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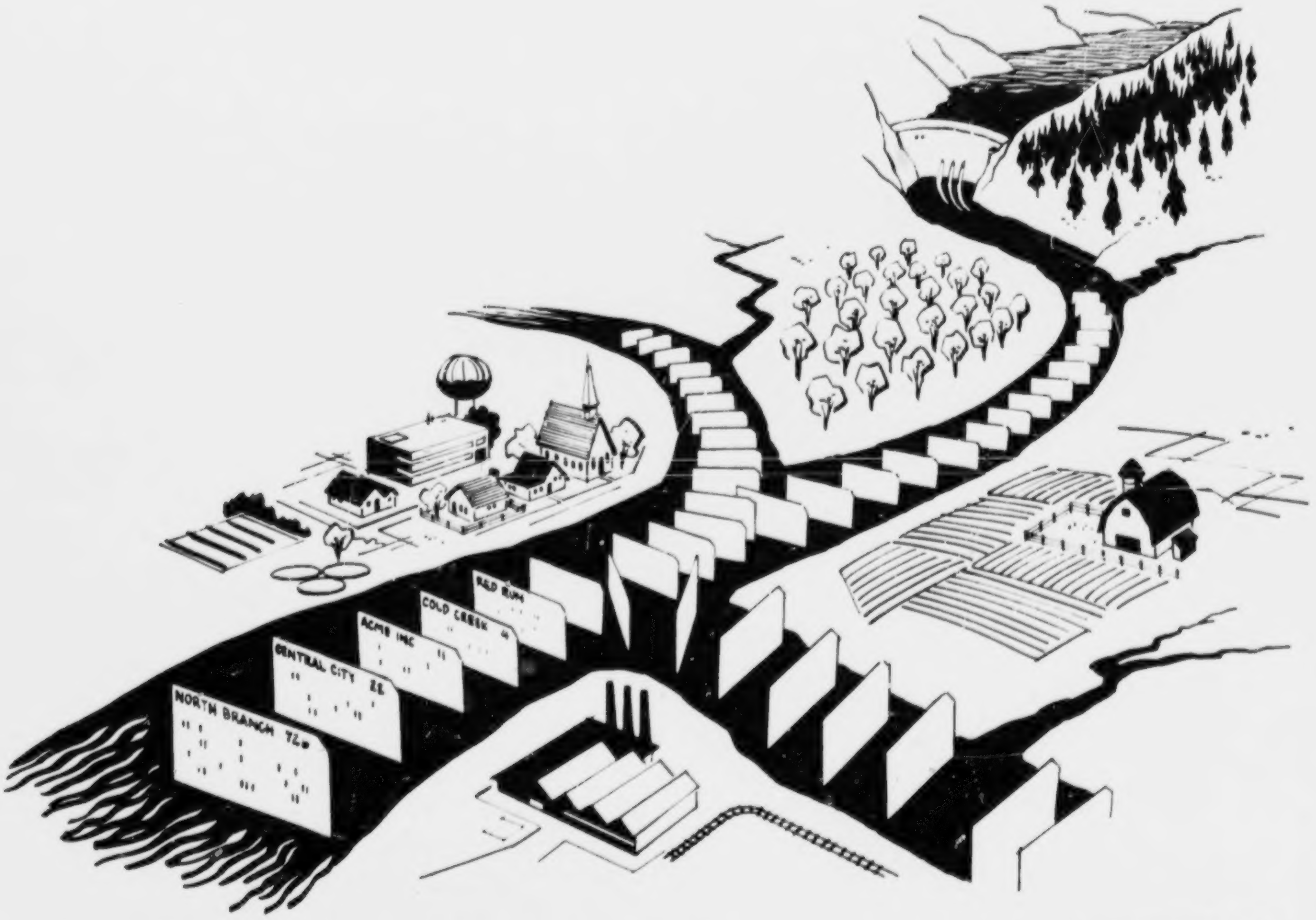
Complementary - Competitive Aspects of Water Storage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27 *Abstract*

Allocation of scarce water for flow augmentation to enhance water quality and other beneficial uses conflicts with other water demands. An analytical model is proposed that is capable of allocating water to competing demands on the basis of economic efficiency. The value of water is determined from the slopes of the benefit functions for water uses and an algorithm, based on the theory of marginal analysis, allocates water after considering the complementary and competitive uses of available water. Operations strategies may be selected and revised throughout the demand period regarding the amount of water to remain in storage, or stored and then released for downstream uses or downstream diversions. Results predict the frequency and magnitude of shortages for each beneficial use of water.

Simulation of the hydrologic and economic systems of the proposed Holley Reservoir in the Willamette Valley in Oregon was used to test the effectiveness of the proposed analytical model and the results appear very good. A daily streamflow model and a relationship between reservoir operation and recreational attendance were developed to produce an accurate simulation of the basin. Planners, designers, and operations personnel are provided with a method of allocating water in proposed and existing systems. This method indicates the value, extent and magnitude of the complementary and competitive aspects of water storage for water quality control.

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WATER POLLUTION CONTROL RESEARCH SERIES

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COMPLEMENTARY-COMPETITIVE ASPECTS OF WATER STORAGE

An Engineering-Economic Approach to Evaluate the Extent and Magnitude of the Complementary and Competitive Aspects of Water Storage for Water Quality Control

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEPARTMENT OF THE INTERIOR

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December, 1969

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This report has been reviewed by the Federal Water Pollution Control Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Pollution Control Administration.

ABSTRACT

COMPLEMENTARY-COMPETITIVE ASPECTS OF WATER STORAGE

KEY WORDS: Allocation; Flow Augmentation; Marginal Analysis; Planning; Reservoir Operation; Simulation; Temperature Control; Water Pollution; Water Quality

Allocation of scarce water for flow augmentation to enhance water quality and other beneficial uses conflicts with other water demands. An analytical model is proposed that is capable of allocating water to competing demands on the basis of economic efficiency. The value of water is determined from the slopes of the benefit functions for water uses and an algorithm, based on the theory of marginal analysis, allocates water after considering the complementary and competitive uses of available water. Operations strategies may be selected and revised throughout the demand period regarding the amount of water to remain in storage, or stored and then released for downstream uses or downstream diversions. Results predict the frequency and magnitude of shortages for each beneficial use of water.

Simulation of the hydrologic and economic systems of the proposed Holley Reservoir in the Willamette Valley in Oregon was used to test the effectiveness of the proposed analytical model and the results appear very good. A daily streamflow model and a relationship between reservoir operation and recreational attendance were developed to produce an accurate simulation of the basin. Planners, designers, and operations personnel are provided with a method of allocating water in proposed and existing systems. This method indicates the value, extent and magnitude of the complementary and competitive aspects of water storage for water quality control.

This report was submitted in fulfillment of Project 16090 DEA between the Federal Water Pollution Control Administration and the Sacramento State College Foundation.

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SECTION 1

SUMMARY

CONCLUSIONS

1. An analytical model has been developed and tested that is capable of indicating the extent and magnitude of the complementary and competitive aspects of water storage for water quality control. Techniques of marginal analysis are used to analyze the benefit functions of water uses and allocate scarce water on the basis of economic efficiency.

2. A daily streamflow simulator has been developed and tested which is capable of generating daily nonhistoric flow sequences with statistical properties and hydrographs similar to historical flows.

3. Reservoir recreation attendance has been analyzed and a definite relationship was developed regarding the influence of reservoir operation on recreational attendance for the area studied.

4. Results from the simulation of the hydrologic and economic systems of the basin studied include a response surface showing the maximum net benefit contours for water quality combinations of dissolved oxygen concentrations of 4, 5, and 7 mg/l and coliform bacteria MPNs of 240, 1000, 2400, and 5000 per 100 ml. Associated costs to achieve the water quality objectives are included. Optimum objectives agree closely with the objectives of the Oregon State Sanitary Authority.[1] The minimum flow objective (6000 cfs) on the basis of economic efficiency was higher than the State's objective (5500 cfs); however, the State's appears to be more realistic in view of the shortages associated with optimum conditions derived from economic simulation models. Water quality management plans based on the State's minimum flow objective would achieve fewer and less severe failures to meet water quality objectives than a higher flow objective.

5. Flow augmentation, as shown by this research project, is an economically feasible means of achieving and maintaining water quality objectives. The extent of flow augmentation is a function of the shape of the hydrograph, the degree of treatment provided, the cost of alternative means of waste treatment, and the value of complementary and competitive beneficial uses of available water.

6. Reliability of flow augmentation is a function of other project purposes and other facilities in the basin. Directly downstream of a reservoir, annual demands should be met or almost met every year. In a large, highly regulated system, with many reservoirs where

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[1] The name of this agency has since been changed to the "Oregon Department of Environmental Quality".

demands for the release of water for flow augmentation many occur only during water short years, a new system may not be too reliable. During water short years, if reservoir operations are based solely on marginal benefit analysis, competing demands may provide greater returns or may have priority in order to meet contractural commitments. Even if water was legally appropriated for specific beneficial uses on the basis of economic efficiency, sufficient water may not be available to meet all of the appropriation demands during drought periods.

7. Storage of water for temperature control accompanied by selective withdrawal both compete with demands for flow augmentation to meet other water quality objectives during certain periods of the year. Frequency and magnitude of shortages in the minimum conservation pool should be similar to shortages in downstream flows in order to achieve maximum fishery enhancement benefits. Available water for fisheries should be allocated between demands to meet flow and also temperature target objectives. The sacrifice of either objective for the other would cause considerable losses, even though one of the objectives was achieved. Therefore, the several demands for fisheries must all be met to some degree since they are all necessary conditions for downstream fishery enhancement.

8. Small, frequent shortages will be encountered by water users and occasional damages from floods will be encountered when economic efficiency is the objective if structural inputs are sized, target outputs are selected, and operational procedures are established on the basis of economic simulation models or mathematical optimization techniques.

RECOMMENDATIONS

1. Techniques are needed to develop accurate benefit functions to describe the economic losses incurred by water users when water shortages occur and/or water of insufficient quality must be used.

2. The feasibility of dynamic allocations of water must be examined. In the future the value of water associated with beneficial uses will change as well as the demands for use. Increased leisure time is expected to be accompanied with more recreational use of water. Higher degrees of treatment will alter the value of water for water quality control. A study of this problem should be attempted and should consider trends in water uses, advances in waste treatment technology, and the influence of an increasing population and an expanding economy on all affected water quality indicators. Current projects should be capable of reallocating water in the future.

3. Institutions are needed that are capable of basin-wide regulation of waste discharges and of land use if available water resources are to be allocated in an optimal fashion.

4. Negative benefits from storage of water for water quality control should be evaluated. Stored water is essentailly the wash water from a basin. When stored water is released for water quality control, the turbidity of downstream waters frequently increases due to suspensions in the wash water and algal growths. If provisions are not made for selective withdrawal, then downstream temperatures could increase or the released water could be low in dissolved oxygen. Existing water contact sports could be curtailed when downstream temperatures are lowered for fishery enhancement.

5. Water quality benefits should be associated with water use benefit functions, rather than to water quality *per se* as allowed in Senate Document 97 (27). Application of Senate Document 97 allowing benefits to be equal to the cost of external alternatives could justify water quality objectives with excessively high associated costs that might not receive sufficient evaluation.

SECTION 2

INTRODUCTION

STATEMENT OF THE PROBLEM

When water is stored and subsequently released for water quality control, two conflicting situations arise. Released water not only normally improves downstream water quality, but also enhances those other downstream beneficial uses of water dependent upon water quality and higher flows. Stored water improves reservoir recreation and fishing, provides head for the production of hydroelectric power and furnishes a conservation pool for regulating the temperature of released water. When water is released for water quality control, a competitive relationship develops, not only between reservoir storage needs, but also between the downstream demands for water to be diverted for such purposes as irrigation. If water is stored for water quality control, the extent and magnitude of the complementary and competitive aspects should be known. An associated problem during water short periods is how much water should be released for what purposes, and when should it be released, as well as how much should remain in storage. Reservoir storage space for the regulation of potential floods frequently conflicts with reservoir filling schedules essential for meeting water demands during low flow periods.

SCOPE AND OBJECTIVES

The specific aim of this project was to investigate the complementary and competitive aspects of water stored for water quality control. To achieve this objective, a rational analytical model using marginal analysis was developed. This model allows the extent and magnitude of the complementary and competitive aspects to be quantified by a comparison with the probability density function of the maximum reservoir storage and expected reservoir inflow during a critical low flow period. A simulation model of the hydrologic and economic systems of a test basin verify the adequacy of the model.

Actual physical, hydrologic, and economic data to test the model were obtained for the Calapooia River near the middle of the Willamette River Basin in Northwestern Oregon. Potential project benefits from the development of the proposed Holley Reservoir in addition to water quality include flood control, irrigation, drainage, downstream fisheries, reservoir sportfishing, and reservoir recreation. Other minor benefits include downstream hydroelectric power generation and navigation which were not included in this study because of their minimal influence in relationship to the other potential project purposes.

Water quality benefits from flow augmentation were estimated on the basis of the postponement of the construction of treatment facilities and the avoidance of maintenance and operation costs of these facilities if the target water quality flow objective was met. This procedure is in accordance with standards for the measurement of water quality control

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benefits as outlined in Senate Document 97 (27). Currently most project planners prefer to evaluate water quality benefits by determining the direct effects of water quality on specific beneficial uses.

Inclusion of flow augmentation in any federal project currently must be in accordance with Section 3 (b) of the Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.), which states that the storage and release of water for flow augmentation shall not be provided as a substitute for adequate treatment or other means of controlling the waste at the source. FWPCA policy has been to interpret "adequate treatment" to mean no less than the equivalent of secondary treatment.

The degree of treatment required to meet combinations of water quality objectives for dissolved oxygen concentrations of 4, 5, and 7 mg/l and coliform bacteria MPNs of 240, 1000, 2400, and 5000 per 100 ml for different minimum flow objectives was determined in two phases. Non-linear programming was used to determine the minimum cost to remove or treat an estimated sufficient amount of waste to achieve the water quality objectives (16). The results were in terms of an allowable discharge for each significant waste discharger(20 municipalities and 7 pulp mills) in the Basin. These results were inserted in an oxygen sag model of the basin by Worley (28) and a coliform die-off model by Kerri (17) and the response of the river system was checked to determine whether the water quality objectives were met. The input data consisted of field data collected during 1963 (4), and cost figures for the 1963-1965 period (17).

Although the model used a minimum cost solution, the results from current loadings would probably not be too different from the results obtained by establishing a uniform effluent requirement. Current Federal Water Pollution Control Administration policy stresses the highest degree of treatment possible, which is consistent with the approved Water Quality Standards for the Willamette River and Multnomah Channel. Current approved standards require "at least 85% removal of BOD and suspended solids plus effluent chlorination" (20). Provisions are included to require a higher degree of treatment if necessary.

Industrial expansion and population growth will cause the 85% removal requirement to be inadequate in the future. If the uniform effluent requirement is accepted and enforced, then at some time in the future all waste dischargers will have to increase their degree of treatment to the 90 or 95% level of BOD and suspended solids removal. At this point, the benefits from the alternative of releasing water for water quality control will be extremely high. A review of previous enforcement action indicates that, with the exception of the city of Portland and the older pulp mills, the Oregon State Sanitary Authority successfully concentrated its early activities along the lower, critical reaches of the Willamette River and on the larger municipalities. This enforcement is consistent with the results from minimum cost models.

A daily streamflow simulator was developed to simulate hydrologic conditions in the basin (21). Originally, it was written in FORTRAN and then in DYNAMO.[2] DYNAMO was found to be a superior computer language than FORTRAN and a very effective research tool for this type of problem. Consequently, the economic system and analysis section of the simulation model were written in DYNAMO. Flow diagrams and copies of the programs are contained in Appendix V.

This project model is not intended to be definitive of Holley Reservoir, but is developed to accomplish the aims of this research project and in order that it be useful for water resource projects of this general nature. At the time (December 1969) this report was completed alternative cost and benefit functions for Holley Reservoir were being developed and reviewed. The actual Holley data lend reality to the investigation and make the results more clearly understood.

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[2] DYNAMO is a simulation language developed at MIT by J. W. Forrester (6) to study problems in industrial dynamics.

SECTION 3

ANALYTICAL MODEL[3]

To identify the extent and magnitude of the complementary and competitive aspects of water storage for water quality control, an algorithm is proposed that incorporates the concepts of dynamic programming and marginal analysis. In the process, available water is allocated to those beneficial uses that produce the greatest return.

Hall, using techniques developed by Bellman (3), has used dynamic programming as the optimizing procedure for selecting the capacity of an aqueduct (7), the design of a multiple-purpose reservoir (8), and water resources development (9). The proposed algorithm is an extension of Hall's observation that the number of calculations could be "drastically reduced" by developing a table of incremental benefits for each function under consideration and selecting the largest remaining increment of benefit for each additional increment of water (7). Beard (2) also has indicated the feasibility of the proposed approach.

An allocation and incremental benefit table provides an excellent illustration of water demands and associated benefits. The proposed model is dynamic from the standpoint that during low flow periods, at the end of each time increment past and expected inflows, available storage, and remaining demands are reviewed and allocations redistributed if necessary to optimize output.

ALGORITHM

1. Identify the time span during which water must be released (low flow period) from storage for beneficial uses. The time of maximum reservoir level will vary from year to year, but the beginning of the demand period can be approximated.

2. Develop benefit functions for beneficial uses creating demands during the low flow period. The benefit functions will show the losses resulting from failure to meet target outputs.

3. Determine the value of water for each segment of the benefit function in dollars per acre-foot.

4. Rank the values of the segments in descending order.

Allocation of Water

5. Begin allocation of water by assuming an empty reservoir.

6. Assume increasing volumes of water available for allocation. The

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[3] The theory and derivation of this model are contained in Appendix I, Theory of Optimum Allocation of Water.

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initial increments may have to be stored before full advanatage may be taken of the most valuable segments of the benefit functions. The sequence of allocation of the segments of the benefit function cannot be ignored because sometimes a low value increment may be associated with minimal storage.

7. Assign priorities to water demands. The total benefit for all possible uses of each increment must be estimated. Possible uses include (1) storage, or storage and then release for either (2) downstream use or (3) downstream diversion. Whichever of the three possibilities that produces the greatest value receives the increment of water under consideration. This step is repeated until all demands are satisfied or the maximum possible volume of available water has been allocated.

8. Estimate the extent and magnitude of the shortages for any beneficial use from the probability or frequency density function of the expected volumes of water available for storage or release. (Reservoir storage plus expected inflow.)

9. Compare results from the algorithm with and without water quality demands. The frequency and quantity of the shortages with and without water quality as a project purpose will indicate the extent and magnitude of the complementary and competitive aspects.

Verification of these results should be obtained from a simulation model of the project under study. Simulation is essential because the response of the basin can be observed using historical or simulated flow sequences.

APPLICATION OF ANALYTICAL MODEL

Planners and designers will find the analytical model an excellent screening tool. The model will be helpful not only in identifying the extent and magnitude of the complementary and competitive aspects, but it will be also applicable to estimating sizes of structural inputs, target outputs, and operating procedures. The model will not be particularly useful in determining flood storage and filling rates because of the importance of flow sequences in determining these factors. Simulation, combined with marginal analysis, is effective in attacking this type of problem.

A very important use of the model should be in determining operational procedures in simulation models and then applying the results to actual facilities. If benefit functions in the simulation model are prepared on the basis of percent target met and percent target benefit, then varying target outputs and appropriately adjusting target benefits will not change the priorities because the slopes of the benefit function will remain the same (Figure 1). Figure 1 shows a typical benefit function where economic losses are encountered whenever the target output (thus the target benefit) is not met.

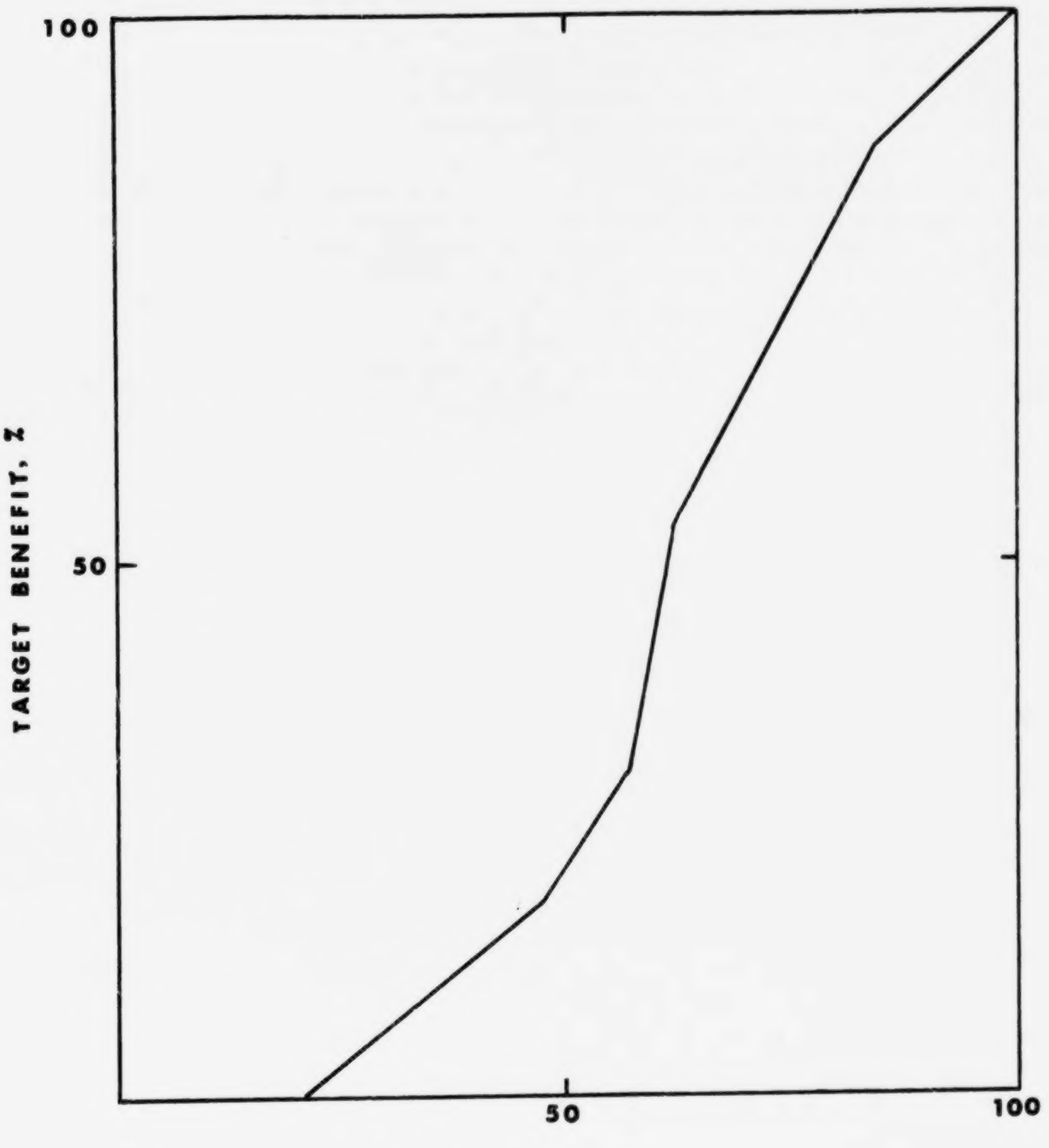

Fig. 1. Typical Benefit Function

Existing systems can be reviewed using the analytical model. Users will have to recognize institutional constraints and delivery contracts. During periods of extreme shortages, the model could be used to allocate the water on the basis of economic efficiency. These results could be compared with alternative means of meeting specific critical demands, such as domestic needs.

In applying the model, either static or dynamic conditions may be assumed. Static conditions consider the situation for the entire critical period without regard for events within the period. Dynamic conditions consider actual inflows, storage and releases on a daily, weekly, or monthly basis within the critical period under consideration and continually revise allocations for maximum economic efficiency. This is consistent with the Bureau of Reclamation's procedure of meeting contractual commitments and then maximizing hydroelectric power production at their facilities (24).

SECTION 4

SIMULATION MODEL[4]

To test the analytical model, a simulation model (Fig. 2) of the hydrologic and economic systems of the Calapooia River Basin (Fig. 3) was developed and tested. Daily increments were used to accurately describe low flow conditions as well as estimating peak flood flows and the routing of the flood hydrographs through the reservoir. Analyses of 200 years of simulation runs (Section 5) indicated that similar results could be obtained from 50-year runs in terms of the expected annual net benefits.

In the hydrologic system, streamflows were generated at the proposed reservoir site (designated upstream hydrology) and at a downstream gaging station three miles above the confluence of the Calapooia River with the Willamette River. Flows in the Willamette River were simulated only during low flow periods at Salem, Oregon, the location of the minimum flow objective station in the Willamette River. Consideration was given to the regulated releases from the other 13 authorized reservoirs in the Willamette Basin System.

Reservoir operational procedures were developed on the basis of two techniques. Releases of storage volumes during low flow periods were allocated to downstream demands and reservoir needs on the basis of results from the analytical model. The complementary and competitive aspects were accounted for in allocating volumes of water for storage and release. Flood control storage and filling schedules were derived on the basis of applying the method of steepest ascent to the results from the simulation model (Section 5).

Economic benefits from meeting water demands for beneficial uses were calculated in the economic model on the basis of a percentage of the target output which was successfully met. Benefit functions (Figure 1 and Appendix IV) attempted to estimate losses incurred by failures to achieve the target output. Losses were measured by subtracting actual benefits from target benefits, where actual benefits are determined from the percent target output met. Project purposes included drainage, flood regulation, irrigation, downstream anadromous fishery enhancement, reservoir sport fishing, recreation, and water quality. Annual costs associated with the project purposes are calculated on the basis of the interest rate,[5] life of facilities, and maintenance and operational costs.

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[4] A summary of the sources of input data is found in Appendix IV. For a detailed description of the model, flow diagrams, and the computer programs in FORTRAN and DYNAMO, see Appendix V. Good explanations of the DYNAMO language may be found in the DYNAMO Users Manual (22) and in a paper by Krasnow and Merckallio (18). For applications of DYNAMO see references 10 and 11.

[5] Any interest rate may be tested in the model and rates between 3 and 5% were studied by this project.

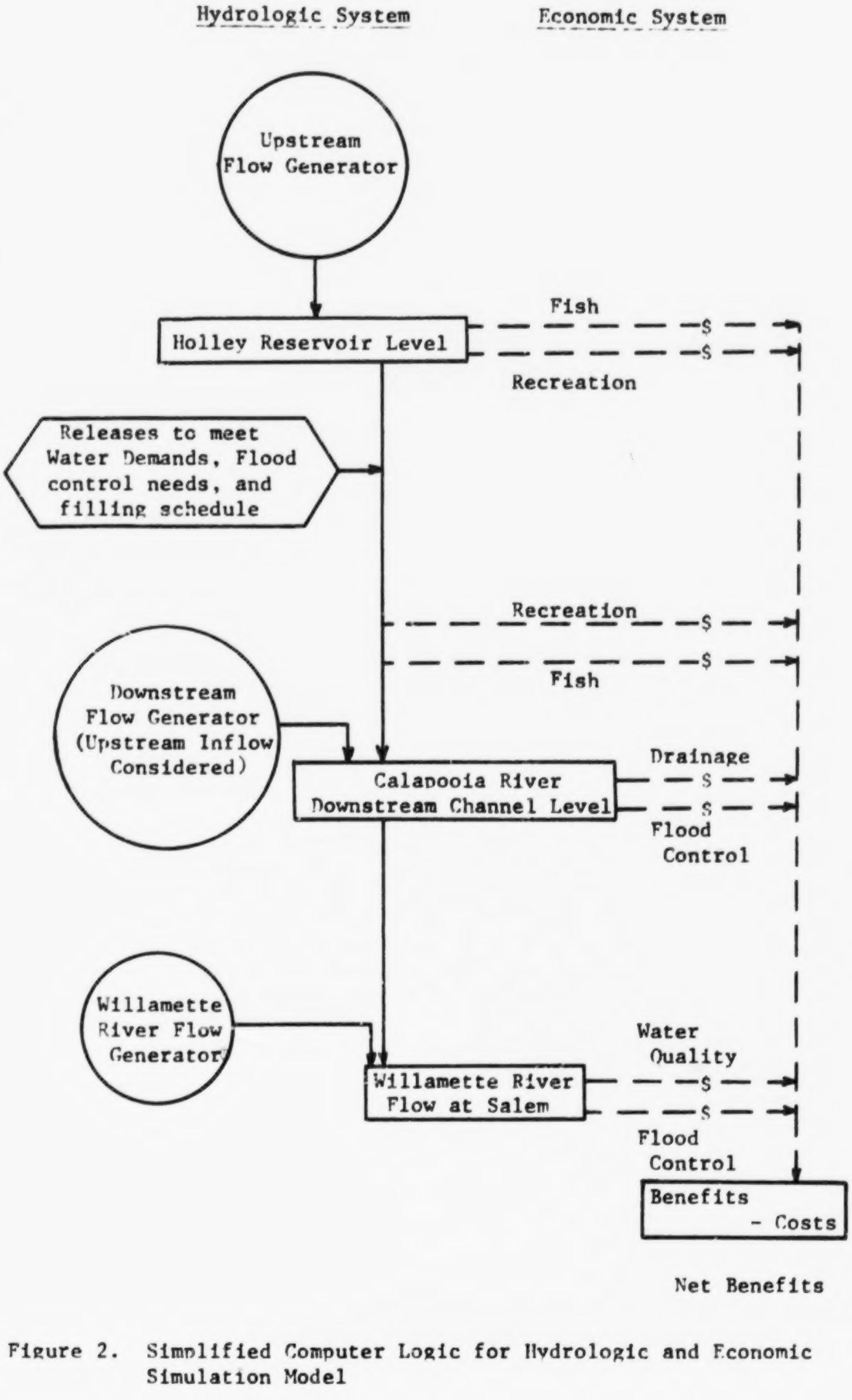
Hydrologic System
Economic System
Upstream Flow Generator
Holley Reservoir Level
Fish
$
Recreation
$
Releases to meet Water Demands, Flood control needs, and filling schedule
Recreation
$
Fish
$
Downstream Flow Generator (Upstream Inflow Considered)
Calapooia River Downstream Channel Level
Drainage
$
Flood Control
$
Willamette River Flow Generator
Willamette River Flow at Salem
Water Quality
$
Flood Control
$
Benefits - Costs
Net Benefits

Figure 2. Simplified Computer Logic for Hydrologic and Economic Simulation Model

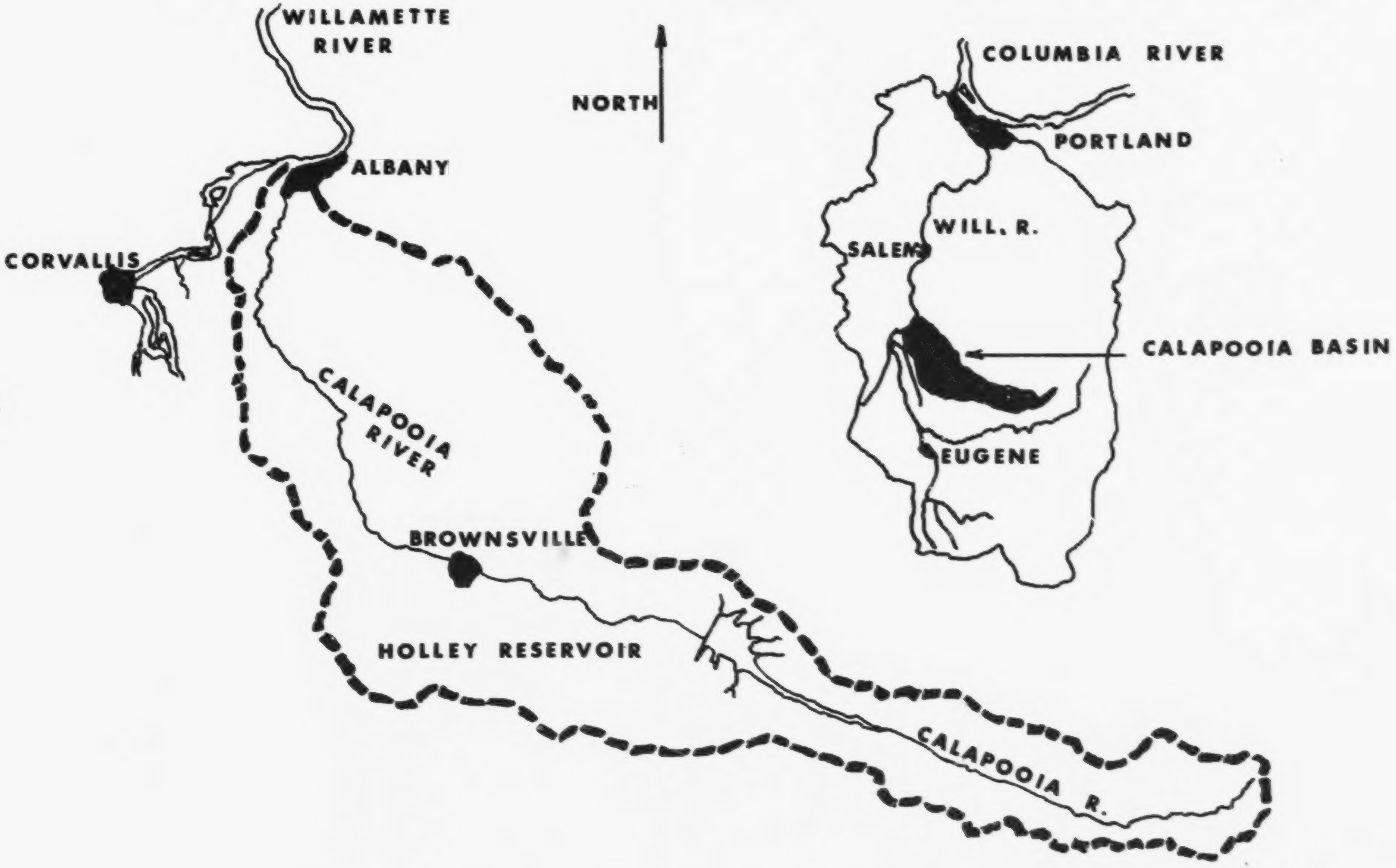
WILLAMETTE RIVER
NORTH
COLUMBIA RIVER
PORTLAND
ALBANY
WILL. R.
SALEM
CORVALLIS
CALAPOOIA BASIN
CALAPOOIA RIVER
EUGENE
BROWNSVILLE
HOLLEY RESERVOIR
CALAPOOIA R.

Fig. 3. Calapooia River Basin

Performance of any proposed system of structural inputs, target outputs, and operational procedures is evaluated by the economic analysis section of the simulation model. Reservoir operation is measured in terms of how close the reservoir came to being full each year, as well as its ability to maintain the minimum conservation pool for temperature control. Spill data and flood regulation ability are also recorded.

Various sized channels below the reservoir are evaluated in terms of the channel's ability to contain reservoir releases and local inflow during flood periods. Also considered are the flows in the channel during the drainage season when the average channel level must be below 30 percent of the channel capacity to receive full drainage benefits.

Irrigation capability is recorded on the basis of the percent irrigation target met. Recreation and water quality are evaluated on a similar basis.

For each project purpose, the economic analysis section records the frequency and magnitude of the shortages for every simulation run. Analysis of these results indicates how the system may be improved to aleviate shortages or increase the maximum net benefits.

Shortage indices (1) for each project purpose also were calculated to assist with the analysis of the project performance. Shortage indices assume that losses from failures to meet target objectives can be estimated on the basis of the square of the percent water shortage.

SECTION 5

DESIGN OF EXPERIMENT AND SENSITIVITY ANALYSIS

This section describes the method of economic analysis, design of experiment, sampling procedures, sensitivity analysis, and optimization techniques used to search the average annual net benefit response surface of the system being studied.

ECONOMIC ANALYSIS

Two types of economic analysis models are possible in simulation studies--static and dynamic (13). In a static model, all capital facilities are assumed to be installed at the start of the simulation period and the demands (for water) remain constant throughout the time period under consideration. A dynamic model is characterized by capital inputs and levels of target outputs changing during the simulation period. Demands may be increased annually or they may be held constant for a particular demand period--say the first fifteen years, and then the size of facilites and the demand could be increased and held constant for another time or demand period.

In planning studies which require estimation of future demands and consideration of the facilities necessary to meet these demands a dynamic model should be used. However, this is a research project whose objective is to develop a model that will produce a rational analytical approach to the evaluations of the magnitude and extent of the complementary and competitive aspects of water storage and release for water quality control. These aspects could become "clouded" if the growth rates used in a dynamic model for the different demands and beneficial uses were not realistic and similar to those that actually could be encountered in the future. Also, in a dynamic model which discounts benefits to the present, severe floods or droughts at the beginning or end of the economic life of the project may have considerable influence on the results. For these reasons, a static economic model was regarded as the better approach to carry out the objectives of this research project.

LENGTH OF SIMULATION RUN

To determine the minimum acceptable length of simulation run while searching the response surface and still expect to approach the population mean annual net benefits, two 100-year simulation runs were compared. The first 100 years used the regular random number generator while a noise element was inserted in the random number generator for the second 100-year run. A noise element will vary the sequence of random numbers generated, thus altering the hydrology by changing the random component in the daily flow simulator and changing the times (years) of occurrence of low flow demands in the Willamette River. Results of the runs are summarized in Table 1 and are shown in Figure 4.

Examination of Table 1 reveals similar answers and 50 years appeared to be a sufficient time period for a simulation run. The simulation runs

TABLE 1. SUMMARY OF AVERAGE ANNUAL NET BENEFITS FOR 200 YEARS OF SIMULATION

AVERAGE ANNUAL NET BENEFITS, $1000		
Year	Regular Run	Run With Noise Element Included
0 - 50	1916	1949
51 - 100	2053	2032
0 - 200	1988	

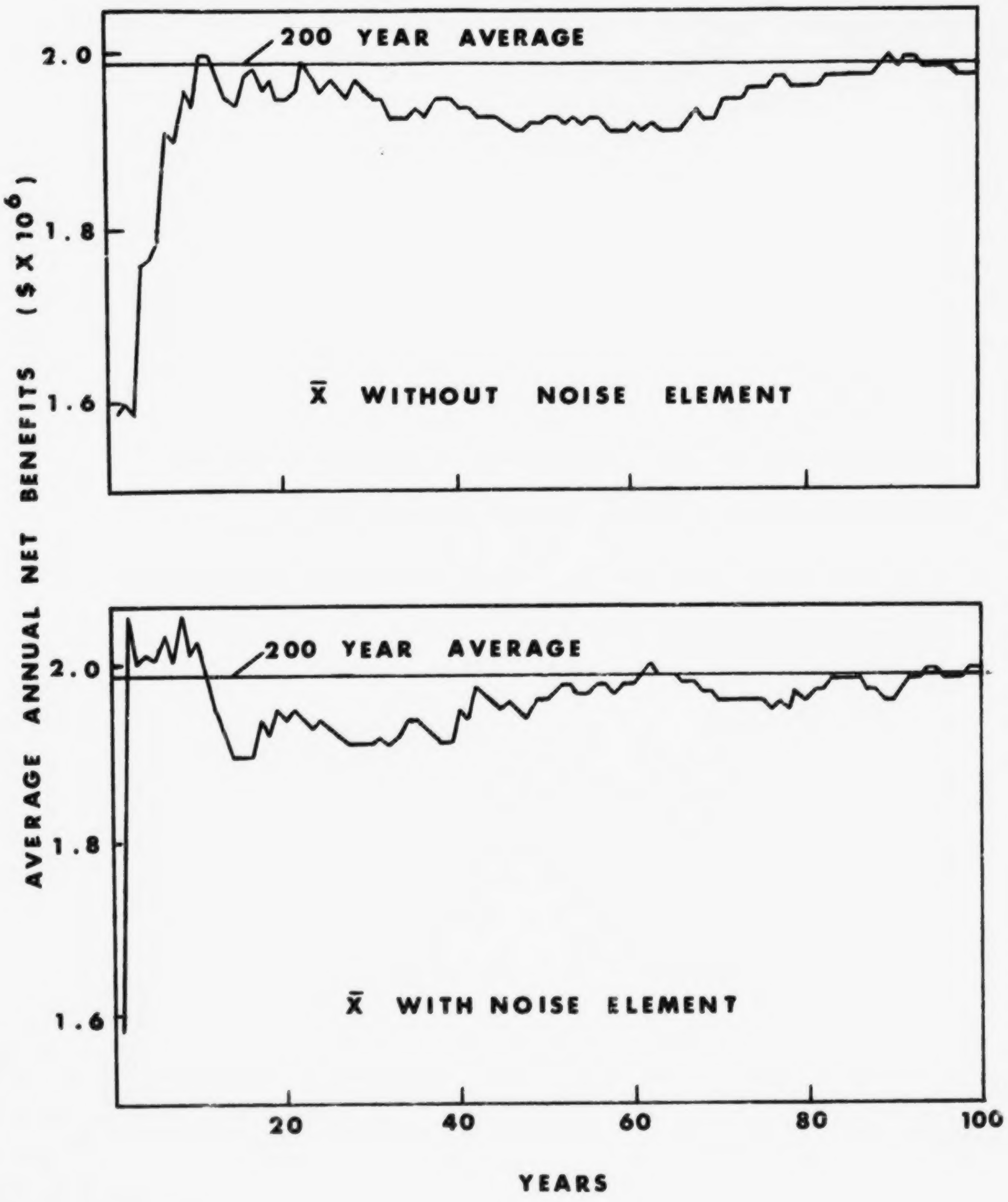

Fig. 4. Two-100 Year Simulation Runs

were broken down into four 50-year periods by separating the second 50 years in both the regular and noise element runs, and the results compared favorably with the 200-year average.

At optimum conditions, the noise element (change in hydrology) caused a shift of 0.7 percent ($2009.7 vs. $1995.9) in the average annual net benefits for a 50-year period. A longer simulation run at optimum conditions will provide an in depth analysis of the system and better indicate its response to adverse conditions.

SENSITIVITY OF BENEFIT FUNCTIONS

Sensitivity of benefit functions is reflected by the slope of a benefit function (Fig. 1). A considerable change in the slope of any benefit function would be required to shift the orders of most demand priorities as determined by the analytical model, because many of the priority values are weighted due to the complementary aspects of water use.

Changing of target outputs does not change the priorities as long as the benefit functions in the simulation model are described in terms of the percent target output and percent target benefit, provided appropriate adjustments are made in the target benefit. Using this technique, the slopes of the benefit functions remain constant. In this simulation model, the only exception was recreation which was a function of the reservoir capacity.

INTEREST RATES

Although the maximum net benefits dropped considerably with increasing interest rates, the structural inputs, target outputs, and operating procedures at optimum conditions were surprisingly stable (Table 2). Current (1969) high interest rates were not anticipated when this study was undertaken. Unless otherwise noted, all results reported are for an interest rate of 3-1/4%.

TABLE 2. MAXIMUM AVERAGE ANNUAL NET BENEFIT, STRUCTURAL INPUT, AND TARGET OUTPUT FOR DIFFERENT INTEREST RATES

Interest Rate %	Reservoir Capacity 1000 Ac-ft.	Irrigation Target 1000 Ac-ft.	Average Net Benefit $1000
3	140	84	2084.1
4	138	84	1780.2
5	138	82	1465.7
SENSITIVITY			
5	140	84	1453.8

Under the sensitivity entry in Table 2 the optimum reservoir capacity (target input) and irrigation target (target output) at a three percent interest rate were used to find the average annual net benefit if the interest rate increased to five percent. The change in average annual net benefits was a decrease of less than 0.5 percent from the optimum net benefits obtained by changing the inputs and outputs to adjust for the increase in interest rates. The importance of these results is that an apparent optimum technological mix exists for this particular basin which is not significantly influenced by varying interest rates.

METHOD OF STEEPEST ASCENT

To find optimum structural inputs, target outputs, and operational procedures, a form of the method of steepest ascent was used. Initially, the methods used by Hufschmidt (12) were attempted. Results were acceptable, but calculations did not produce new bases which were converging on optimum conditions as rapidly as desired. A visual examination of the results and application of the concepts of the method of steepest ascent proved to be the most efficient approach to converging on the maximum net benefits.

OPERATING RULE CURVES

Considerable interest has developed recently in the field of reservoir operation to optimize reservoir yields. James (14) economically derived operating rules which maximized benefits. A stochastic linear programming model was structured by Loucks for defining reservoir operating policies (19). Jaworski (15) and Young (29, 30) used dynamic programming to develop operating rule curves. Young (31) presents a numerical flow routing approach for assessing reservoir requirements for insuring that releases equal or exceed those flows necessary for pollution control. The approach used in this project to determine operating rule curves considers flow sequences, costs of storage, and benefits from water, including economic losses resulting from shortages.

During critical low flow periods, water was allocated, stored, and released on the basis of the analytical model. Flood control storage and filling schedules were developed using the previously described modification of the method of steepest ascent.

Critical decision variables included the volume of flood control storage, when filling should commence, and the rate of filling. Different combinations of these variables were tried using the concepts of the method of steepest ascent in the search for the optimum operating procedures during the flood season and reservoir filling period.

Another approach is to operate the reservoir during the flood and filling seasons on the basis of the condition of the basin. A series of rule curves based on the API (antecedent-precipitation index) or the snow pack are other possible approaches which have application in practice, but could not have been incorporated in the model due to the method of simulating streamflows. For example, if the snow pack is significant, then capacity should be provided to contain a sudden runoff. Operations decisions also should be aided by weather forecasts. These other approaches are particularly helpful to action agencies whose design criteria require the routing of historical records. If the historical records include a late winter or early spring flood which must be regulated, then it is extremely difficult to fill a reservoir during dry years to meet low flow demands, without using the API or a similar concept to operate a reservoir.

Figure 5 shows the first rule curve attempted and final optimum rule curve. A total of 16 different curves were tested. Of particular importance was the filling schedule. On October 1 (Day 1), the beginning of the water year, the actual reservoir level was usually slightly above the minimum conservation pool. Some water should be available for fishery releases and to maintain the pool. The flood season usually begins around November 15 (Day 45). Note that gradual filling of the reservoir begins on December 15 (Day 75), before the most severe floods usually occur. Gradual filling of the reservoir continues until the summer demand period which starts around June 1 (Day 242).

Analysis of the final rule curve reveals that low flow demands produce greater benefits than the reduction of damages due to occasional large floods. Personnel with action agencies have indicated that it is difficult to economically justify providing flood control storage for large floods (26); however potential loss of life is a constraint on the reduction of flood control capacity.

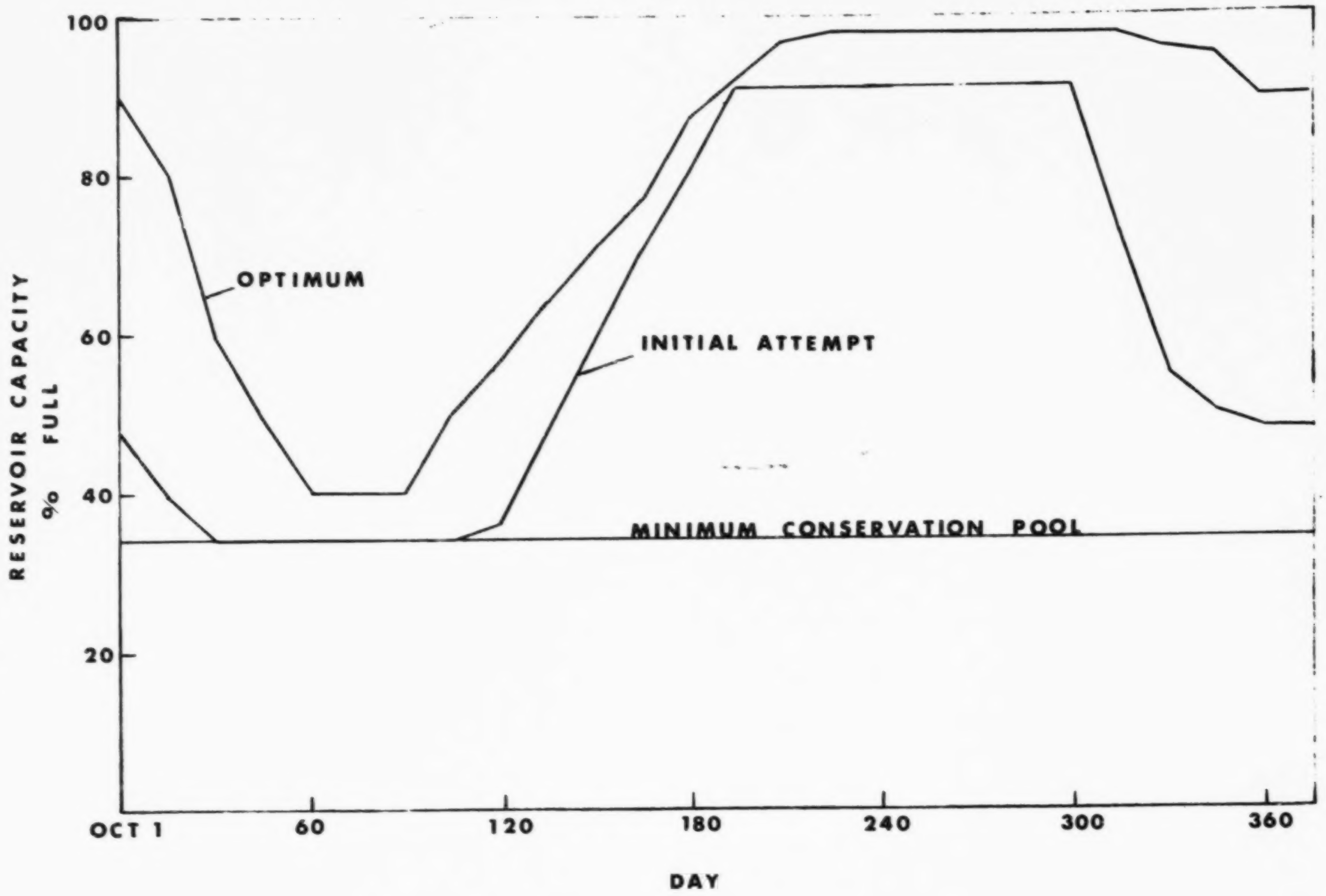

Fig. 5. Operating Rule Curves

SECTION 6

RESULTS AND DISCUSSION

Contained in this chapter is the insertion of actual data from the proposed Holley Reservoir Project into the algorithm of the analytical model. Results from the model are compared with results from the simulation of the hydrologic and water resource related economic systems of the basin. A discussion of the complementary and competitive aspects of water storage for water quality control is based on interpretation of results.

Optimum combinations of water quality objectives are illustrated by a response surface showing the average annual net benefits for combinations of dissolved oxygen concentrations of 4, 5, and 7 mg/l and coliform bacteria levels of 240, 1000, 2400, and 5000 per 100 ml. Flow augmentation objectives should be selected on the basis of the shape of the low flow hydrograph, the value of competing demands, and the costs of waste treatment and water storage. Optimum water quality objectives determined by the proposed analytical model agree closely with actual water quality standards adopted by the Oregon State Sanitary Authority and approved by the Federal Water Pollution Control Administration. A serious shortcoming of mathematical optimization techniques is found in the frequent, small water shortages that are encountered at optimum inputs, target outputs, and operational procedures.

RESULTS FROM ANALYTICAL MODEL

To test and verify the proposed analytical model, the authorized U.S. Army Corps of Engineers Holley Reservoir project was selected on the basis of previous work in the area and the availability of data. Results are not intended to be definitive of Holley, but will be useful for water resource projects of this general nature. At the time (December 1969) this report was completed, alternative cost and benefit functions for Holley Reservoir were being developed and reviewed. Verification of the proposed model was accomplished using the mathematical simulation model of the hydrologic and water related economic systems in the Calapooia River Basin. Details of the input data and benefit functions are contained in Appendix IV. A description of the simulation model, computer flow diagrams, and the actual programs are found in Appendix V.

Results of the application of the proposed analytical model to Holley data are outlined in the following section. The numbering of the steps corresponds to the algorithm outlined in Section 3, Analytical Model.

Algorithm Procedures

1. Identify critical demand period.
   Stored water must be released from Holley Reservoir to meet irrigation demands and downstream fishery enhancement during the months of April, and May. During June, July, August, and September, the dry season, shortages may become acute because of demands to store water for

temperature control, recreation, and reservoir sport fishing, as well as additional releases for flow augmentation for water quality control. Consequently June, July, August, and September were identified as the critical time period.

2. Develop benefit functions. Results are outlined in Appendix IV.

3. The values of water for each segment of the benefit functions are summarized in Table 3.

4. Rank the values of the segments of the benefit functions in descending order as shown in Table 4.

5. Begin allocation of water by assuming an empty reservoir.

6. Assume increasing volumes of water available for allocation as shown in Table 5. Note that priorities A and B are allocated to reservoir storage in order to gain some control over the temperature of released water to enhance the downstream fishery.

7. Assign priorities to water demands. The benefit for all possible uses of each increment must be estimated. Possible uses include (1) storage, or storage and then release for either (2) downstream use or (3) downstream diversion. Incremental values are obtained from Tables 3 and 4 and the benefits estimated for each of the three possible types of uses. In priorities 1, 2, 5, and 6, maximum benefits were obtained by storing a portion of the water for temperature control for anadromous fish and releasing some of the water to maintain a minimum flow and also to improve the DO level to enhance the anadromous fishery.

8. Estimate the extent and magnitude of the shortages for any beneficial use from the probability or frequency density function of the expected volumes of water available for storage or release. (Reservoir storage plus expected inflow.) See Table 4.

9. Examination of Table 5 allows a visual comparison of the extent and magnitude of shortages with and without water quality as a project purpose. If water quality was not a project purpose, then irrigation priorities 3 and 6 should be inserted ahead of priorities 1 and 2. Removal or omission of the water quality project purpose would cause a loss in the anadromous fishery due to dissolved oxygen deficiencies and loss of temperature control.

10. Verification of the results using the algorithm are checked using the mathematical simulation model of the basin. Results may be compared in Table 4. Frequencies of shortages were closely estimated by the algorithm as compared with results from simulation of the system. Fewer shortages were expected by the algorithm because its estimates are based on perfect knowledge, whereas in simulation and actual practice, the exact sequence of future flows is not known.

TABLE 3. INCREMENTAL DOLLAR BENEFITS FROM USES OF WATER[1]

	Value[2]	Incremental Volume[2]
Irrigation		
	$14.2 per ac-ft	67,200 ac-ft
	11.0 per ac-ft	16,800 ac-ft
Fish		
	Reservoir Sport Fish	
	$ 0.80 per ac-ft	10,200 ac-ft
	2.30 per ac-ft	10,200 ac-ft
	6.00 per ac-ft	10,200 ac-ft
	3.00 per ac-ft	20,400 ac-ft
	0.80 per ac-ft	10,200 ac-ft
	Anadromous Fish (Release)	
	Base Release, No Benefit	10,000 ac-ft
	$50.90 per ac-ft	5,000 ac-ft
	17.00 per ac-ft	10,000 ac-ft
	4.20 per ac-ft	5,000 ac-ft
	Anadromous Fish (Storage)	
	Base Storage, No Benefit	20,400 ac-ft
	$24.80 per ac-ft	10,200 ac-ft
	8.30 per ac-ft	20,400 ac-ft
	2.10 per ac-ft	10,200 ac-ft
Recreation		
	$ 7.70 per ac-ft	20,000 ac-ft
	3.30 per ac-ft	40,000 ac-ft
	2.80 per ac-ft	10,000 ac-ft
	2.00 per ac-ft	10,000 ac-ft
	1.85 per ac-ft	20,000 ac-ft
	1.45 per ac-ft	40,000 ac-ft
Water Quality		
	$12.20 per ac-ft	2,900 ac-ft
	8.20 per ac-ft	4,800 ac-ft
	4.90 per ac-ft	38,900 ac-ft

---

1. This table is a summary of benefit functions in Appendix IV.

2. The values and volumes associated with each benefit are ranked in order of allocation, i.e., the first value results from the first incremental volume allocated to the beneficial use.

TABLE 4. RANKED SEGMENTS OF BENEFIT FUNCTIONS

Rank	Fish Res.	Fish[1] Anad.	Irrig.	Recreation	Water Qual.		Vol. Ac-ft.	Cum. Vol.
1		16.8[2]				r&s[3]	15,200	15,200
2			14.2			r	59,100	74,300
3					12.2	r	2,900	77,200
4			11.0			r	14,900	92,100
5					8.2	r	4,800	96,900
6				7.7		s	20,000	116,900
7	6.0					s	10,200	127,100
8		5.6				r&s	30,400	157,500
9					4.9	r	38,900	196,400
10				3.3		s	40,000	236,400
11	3.0					s	20,400	256,800
12				2.8		s	10,000	266,800
13	2.3					s	10,200	277,000
14				2.0+		s	10,000	287,000
15				1.85		s	20,000	307,000
16				1.5		s	40,000	347,000
17		1.4				r&s	15,200	362,200
18	0.8					s	10,200	372,400

1. Approximately one-third of volume is released (5000 ac-ft) and two-thirds stored (10,200 ac-ft)

2. Computed as follows from TABLE 3

$$\$16.8 = \frac{(\$50.90/\text{ac-ft})(5000\ \text{ac-ft}) + (\$24.80/\text{ac-ft})(10{,}200\ \text{ac-ft})}{(15{,}200\ \text{ac-ft})\ 2^{*}}$$

*2 is used to average benefit between storage and release.

3. r, release; s, storage.

TABLE 5. ESTABLISHMENT OF OPERATIONAL PRIORITIES BASED ON COMPLEMENTARY USES

Pri- ority	Volume Ac.ft.	Cum. Storage Ac.ft.	Cum. Release Ac.ft.	Total Increment Benefit $/Ac.ft.	Increment. Benefits $/Ac.ft.		Uses
					s	r	
A	10,000s	10,000		8.5	7.7		Recreation
					0.8		Res.Sport Fish
B	10,000s	20,000		5.0	7.7		Recreation
	10,000r		10,000		2.3		Res.Sport Fish
					0	0	Anadrom.Fish
1	6,100s	26,100		27.0		12.2	Water Quality[1]
	2,900r		12,900		6.0		Res.Sport Fish
					12.4	25.4	Anadrom.Fish
					3.3		Recreation
2	4,500s	30,600		25.6		8.2	Water Quality
	2,100r		15,000		6.0		Res.Sport Fish
					12.4	25.4	Anadrom.Fish
					3.3		Recreation
3	59,100r		74,100	14.2		14.2	Irrigation
4	10,200s	40,800		12.1		6.7	Water Quality
	5,000r		79,100		3.0		Res.Sport Fish
					4.2	8.5	Anadrom.Fish
					3.3		Recreation
5	10,200s	51,000		11.4		4.9	Water Quality
	5,000r		84,100		3.0		Res.Sport Fish
					4.2	8.5	Anadrom.Fish
					3.3		Recreation
6	14,900r		99,000	11.1		11.1	Irrigation
7	10,200s	61,200		5.7		4.9	Water Quality
	5,000r		104,000		0.8		Res.Sport Fish
					1.0	2.1	Anadrom.Fish[2]
					3.3		Recreation
8	16,600r	61,200	120,600	4.9		4.9	Water Quality
9	8,800s	70,000		2.8	2.8		Recreation
	10,000s	80,000		2.0	2.0		Recreation
	20,000s	100,000		1.8	1.8		Recreation
	40,000s	140,000		1.5	1.5		Recreation

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s = Store r = Release

[1] Water for irrigation, water quality, and anadromous fish must be stored before it is released for downstream use; therefore, recreation will benefit during the storage period. These benefits are assigned directly to the recreation benefit to avoid double counting.

[2] Not all of the releases for anadromous fish are applicable to water quality. During some years, the minimum flow target in the Willamette River is met independent of releases below the reservoir for downstream fishery enhancement.

TABLE 6. FREQUENCY DENSITY FUNCTION OF WATER AVAILABLE FOR ALLOCATION

Available Volume, 1000 ac-ft	Expected Freq. in 50 yrs	From Priority	Table V Cum. Demand	Shortages	
				No. of Times Expected (algorithm)	No. of Times (Simulation Run)
125-130		4	119,900	0	0
120-135	1	5	135,100	1	6
135-140					
140-145	1				
145-150	3	6	150,000	5	10
150-155	3				
155-160	22				
160-165	17	7	165,200	47	50
165-170	1				
170-175	2				

To check the ability of the analytical model to properly establish priorities, the most sensitive priorities in Table 5 were switched. The difference between the marginal benefits of priorities 5 and 6 is \$0.3 per ac-ft. When priorities were established from Table 5 the average annual net benefits were 1995.9 thousand dollars. Reversing priorities five and six caused a decrease in average annual net benefits to 1991.9 thousand dollars. Therefore results from a simulation with reversed priorities verified the original order and the analytical model.

DISCUSSION OF COMPLEMENTARY AND COMPETITIVE ASPECTS

Complementary features of storing and releasing water can be visualized by comparing the data in Tables 4 and 5 as shown in Figure 6. Note that the benefits from available water are greater for the smaller volumes because of the multiple uses whereas the competitive benefits (each demand considered individually) are higher for higher volumes because these uses were not combined with earlier demands that have already been met. Marginal costs of storage also are provided for comparison purposes.

To illustrate the contribution to the maximum net benefits, Figure 7 shows the increase in net benefits if water quality is a project purpose. This contribution is measured by avoided treatment costs; however, other beneficial uses also would suffer if adequate water quality in the receiving waters was not maintained.

Particularly disturbing is the high standard deviation at maximum net benefits and at other combinations of inputs and outputs. The standard deviation is a measure of the stability of a particular design. The lower the standard deviation, the greater the utility of the project to the persons influenced by it in terms of a reduction in the uncertainty of the response of the project. Dorfman (5) has proposed that the cost of uncertainty be subtracted from the expected net benefits. The cost of uncertainty is a measure of the loss of utility suffered by water users resulting from the losses they may encounter in the future due to water shortages. If we measure the cost of uncertainty as

$$\text{Cost of Uncertainty} = v_\alpha \sigma / \sqrt{2r} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

where v_α is the normal deviate with probability α of being exceeded, α is the specified probability that a fund to cover the costs of uncertainty will be exhausted, σ is the standard deviation of the annual net benefit distribution, and r is the rate of interest. If $v_\alpha = 0.05$ is 1.645 and r is 3.25%, then the cost of uncertainty is 6.5σ.

Examination of the results from the simulation model showed that a major portion of the standard deviation was contributed by the flood control benefits. In some years there were no flood threats and thus, no flood benefits from the project, whereas in other years the project reduced damages from very serious flood threats.

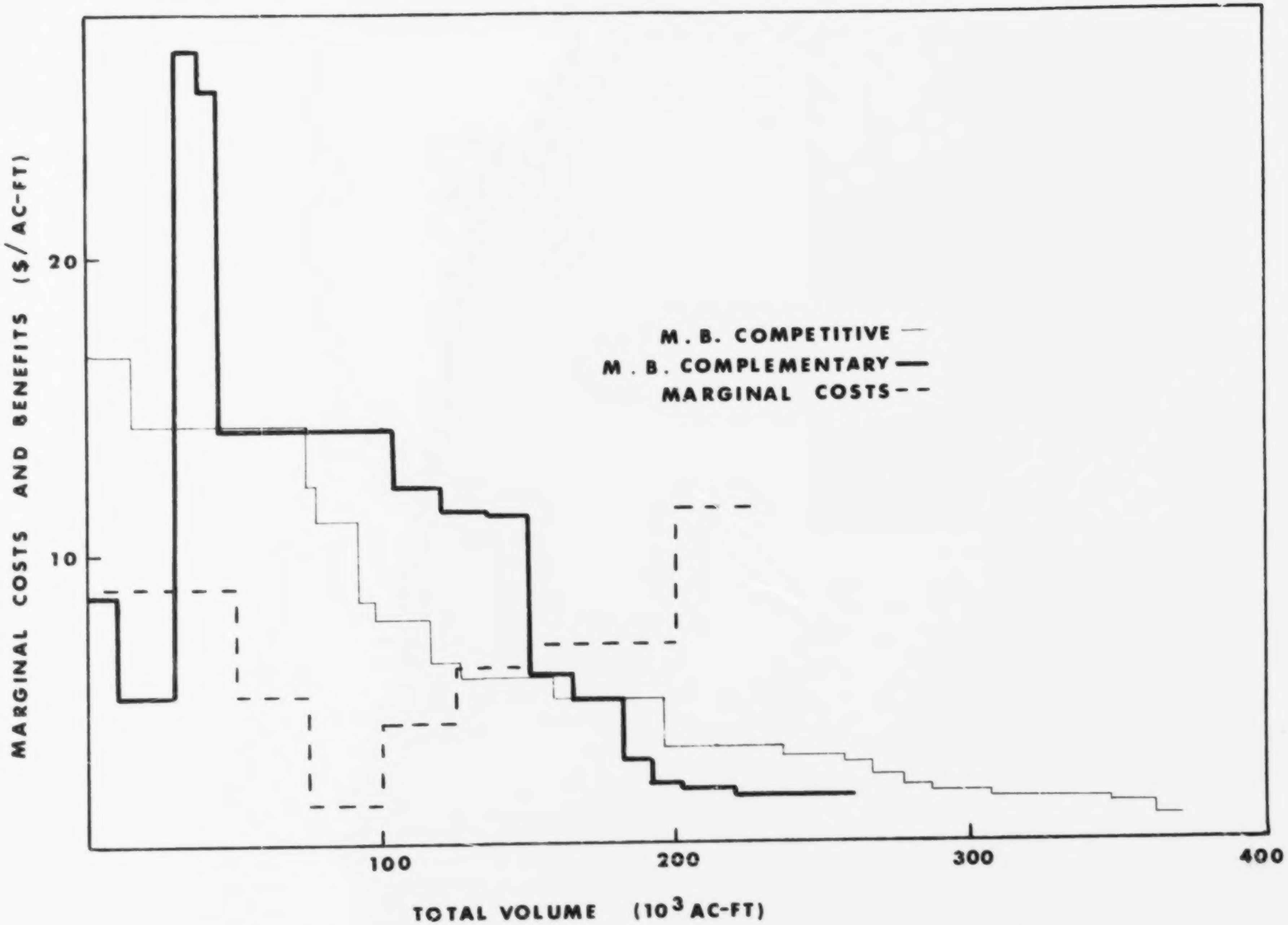

Fig. 6. Illustration of Value of Complementary Factors

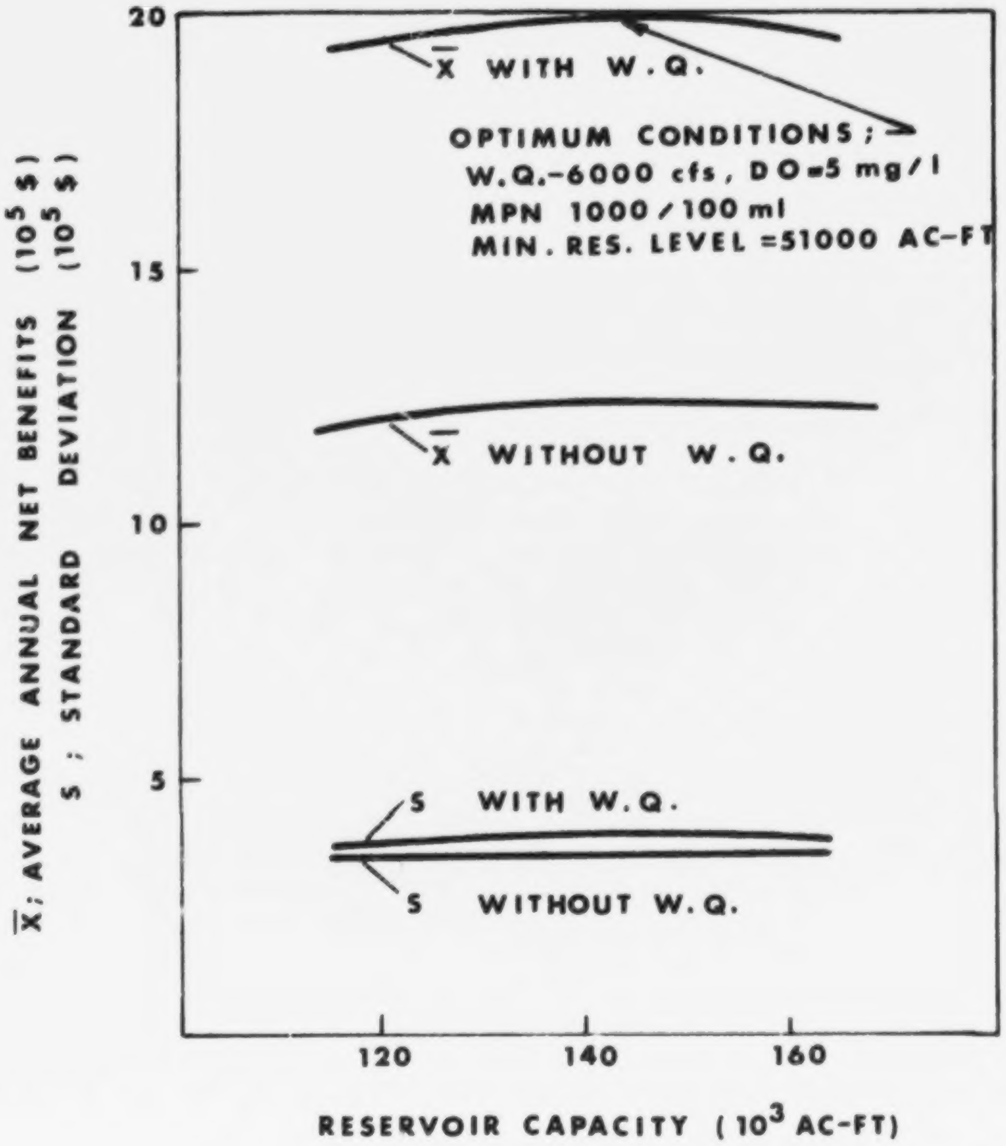

Fig. 7. Average Annual Net Benefits and Standard Deviations, With and Without Water Quality

To examine the sources of losses, the losses from the inability to meet water demands were examined. Losses were recorded every year for recreation from the inability to keep the reservoir full during the entire recreation season because of competitive demands. Shortages also were recorded occasionally resulting from insufficient water to meet water quality demands, storage for temperature control, releases for minimum downstream fish flows, and irrigation demands. At maximum net benefits the average annual loss was \$133,600 with a standard deviation of \$166,000 with a minimum loss of \$45,800 from recreation losses only to a maximum of \$489,500 for all uses. Increasing the reservoir capacity from 140,000 ac.ft. to 160,000 ac.ft. reduced the average annual loss to \$89,500 and the standard deviation of the losses from shortages to \$71,100. The minimum annual loss was \$31,100 and the maximum was \$346,200. The average annual net benefit dropped from \$1,995,900 to \$1,914,800. Annual losses may be seen in Figure 8.

WATER QUALITY RESPONSE SURFACE

An important water quality management decision is the establishment of water quality objectives or standards and a minimum target for flow augmentation. Average annual net benefits for combinations of water quality objectives of a dissolved oxygen concentration of 4, 5, and 7 mg/l and coliform bacteria most probable numbers of 240,1000, 2400 and 5000 per 100 ml were determined by the simulation model. A minimum flow objective of 6000 cfs at Salem, Oregon, produced the maximum net benefit.[6] To account for the associated costs to society for treatment to achieve the water quality objective. The minimum level of treatment for the objectives under consideration (DO = 4 mg/l and MPN = 5000/100 ml) was selected as a base, and the additional annual cost of treatment to each waste discharger was subtracted from the average net benefits from the simulation model. Figure 9 shows the resulting response surface.

Probably the greatest deficiency in the resulting water quality response surface was the method of estimating water quality benefits. Measurement of water quality benefits "by the most likely alternative" (27) essentially insures the benefits exceed the costs. This approach also favors higher water quality objectives due to the higher costs that could be avoided by flow augmentation. These higher costs may not reflect the true benefits to society from higher levels of water quality which could create a better aquatic environment for fishing and swimming.

The shape of the response surface in Figure 9 is not similar to a benefit response surface with benefits increasing as quality improves

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[6] Normally one would expect the minimum flow augmentation target to vary with water quality objectives, but 6000 cfs was the optimum target in this situation because it is the flow target regulated by the releases from thirteen other reservoirs.

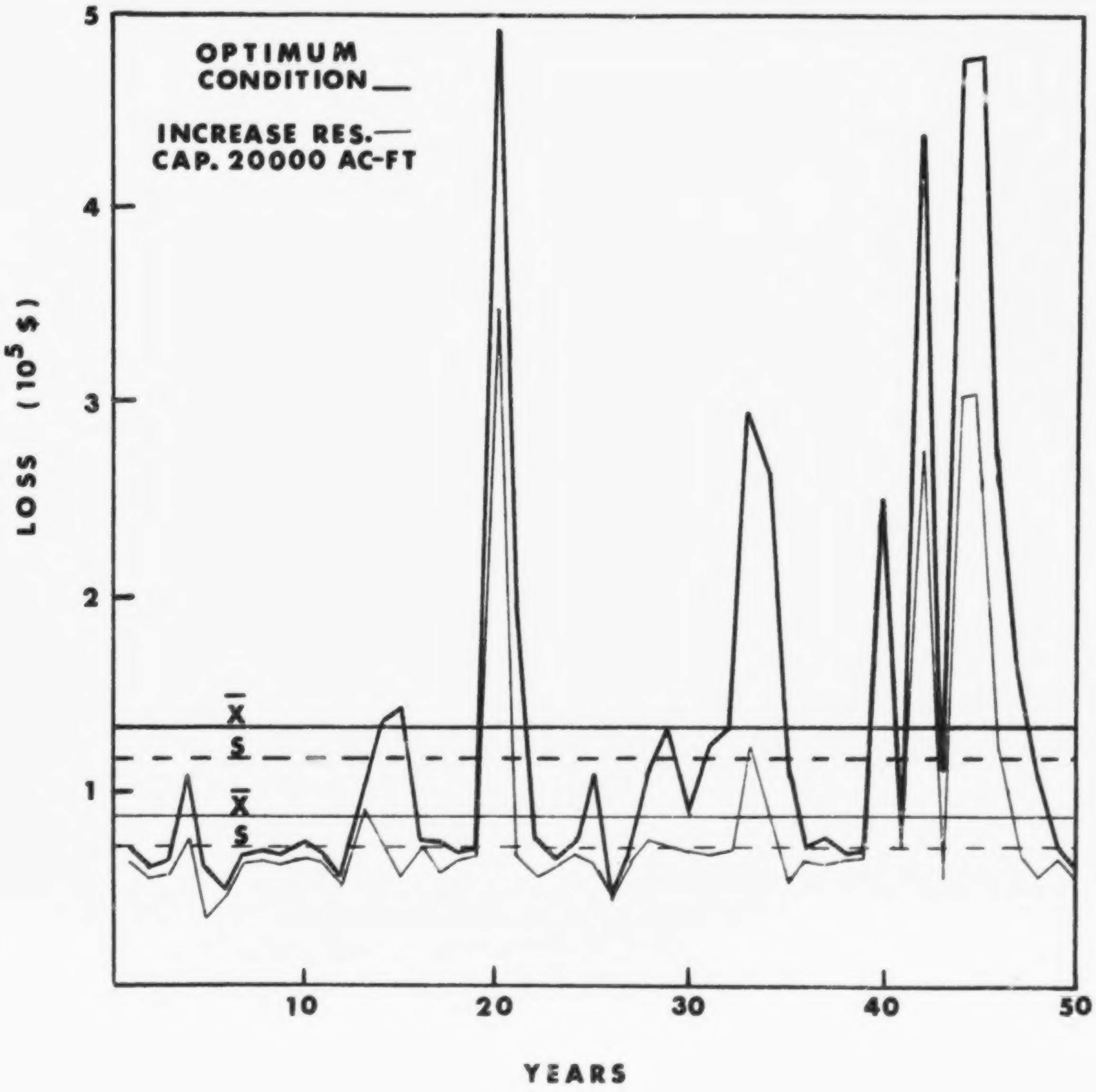


Fig. 8. Annual Losses Due to Water Shortages

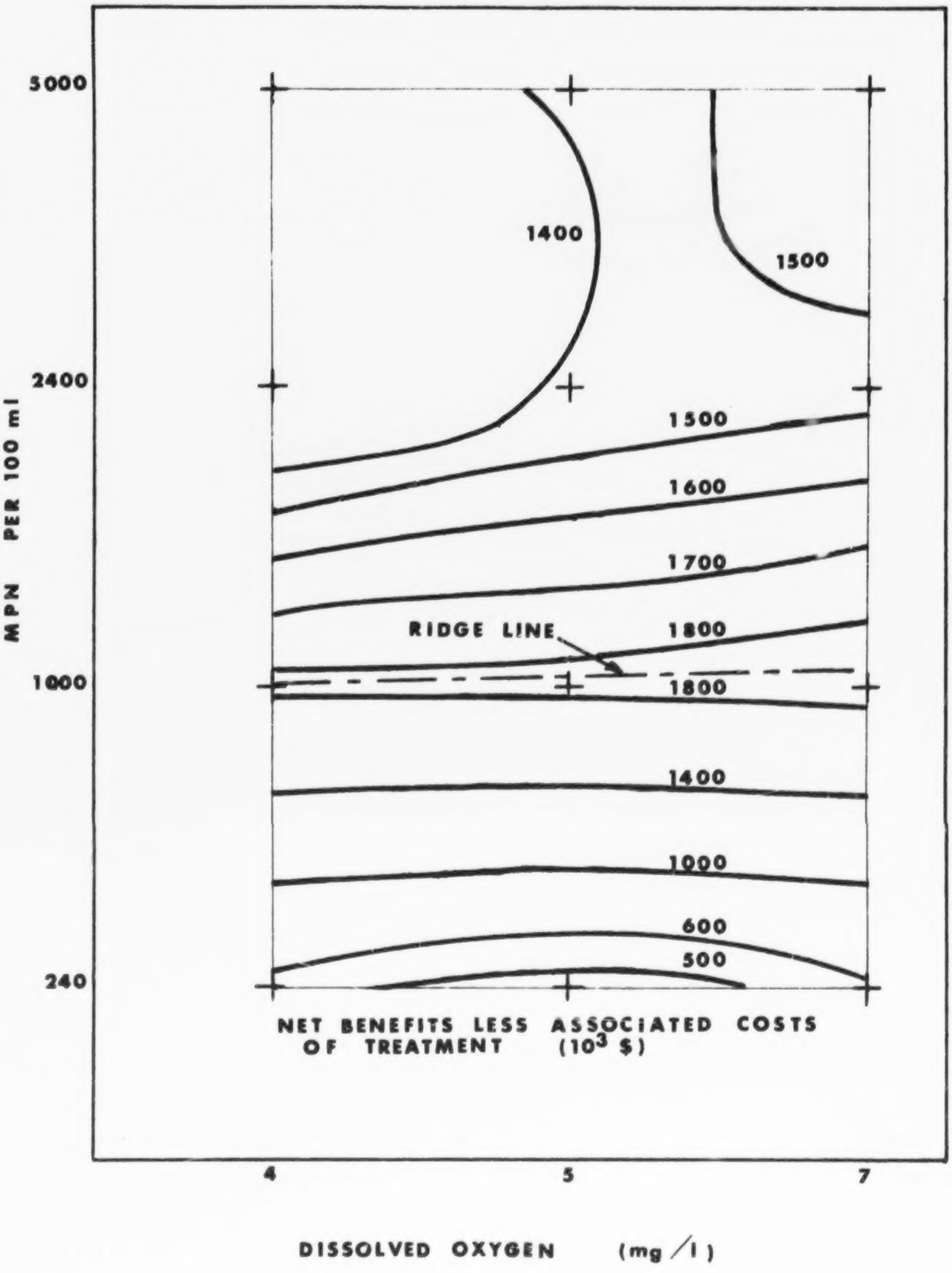


Fig. 9. Water Quality Benefit Response Surface

for several reasons. Associated costs have a profound influence when included in a response surface. These costs of treatment incurred by each waste discharger in order to achieve and maintain the water quality objectives in a basin at the optimum level of flow augmentation may be extremely high in comparison with the benefits associated with high levels of water quality. Other factors influencing the response surface include the method of measuring benefits and actual benefits associated with each level of water quality. Interest rates and fixed and variable costs of waste treatment also are influential. Theoretically one would expect the response surface of Figure 9 to reveal an optimum combination of dissolved oxygen and coliform bacteria by exhibiting a distinct peak somewhere on the response surface, but this did not occur due to some of the reasons given above which influence the response surface.

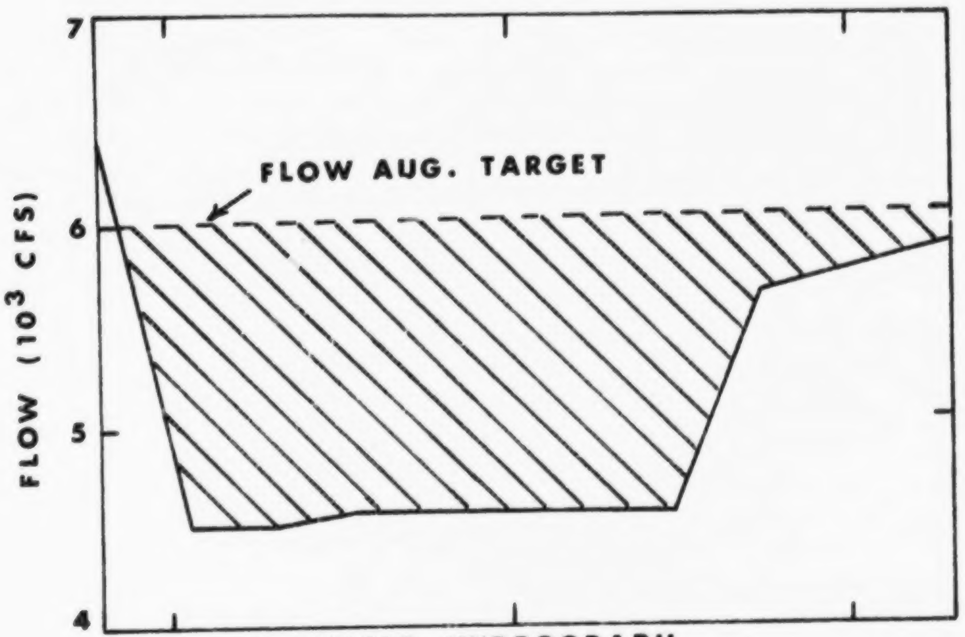
Examination of the response surface and a review of the data plotted show that the optimum combination of water quality objectives would be a dissolved oxygen concentration of 7 mg/l and a coliform bacteria level of 1000 per 100 ml. A drop in the dissolved oxygen objective to 5 mg/l would cause the project benefits to drop 3 percent. Optimum water quality objectives were selected at a dissolved oxygen concentration of 5 mg/l and an MPN of 1000/100 ml because the drop in benefits would be slight and the fact that the benefits were believed to be more accurate at this level.

FEASIBILITY OF FLOW AUGMENTATION FOR WATER QUALITY CONTROL

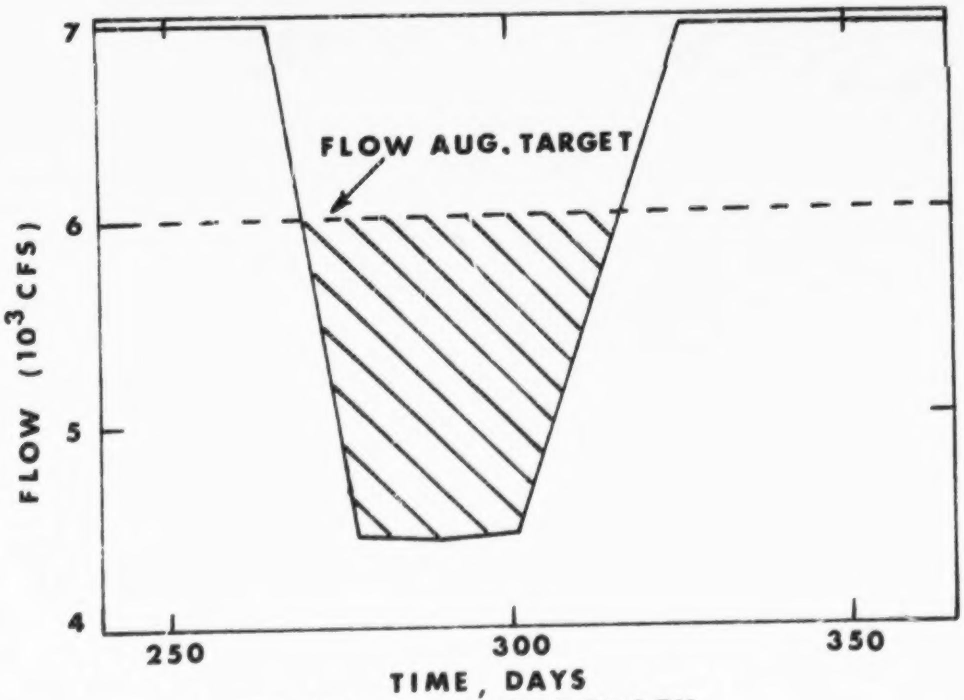
Flow augmentation for water quality control is usually feasible when low flow hydrographs are V-shaped (minimum flows occur during a short time period) and its effectiveness is reduced when the hydrographs become U-shaped, such as could be expected in basins with several reservoirs and where flows are highly regulated. These different shapes of hydrographs are shown in Fig. 10.

If in two identical basins all conditions were alike with the exception of the shape of the hydrographs, then the optimum level of flow augmentation could be considerably different. Comparison of the two hydrographs in Figure 10 reveals that the volume of water (shaded area) necessary to increase the minimum flow level is relatively small for the V-shaped hydrograph in comparison with the U-shaped hydrograph. If benefits are estimated on the basis of different levels of target minimum flow, then the small volume of water in the V-shaped hydrograph becomes very valuable because it is very effective in increasing benefits.

The large volume of water required by the U-shaped hydrograph is not very valuable on a dollar per ac-ft basis (determined from total benefits) and this volume may not even be available for distribution because of higher valued competitive demands. In this case, the cost of additional waste treatment may be considerably less than the cost of additional storage.



U-SHAPED HYDROGRAPH



V-SHAPED HYDROGRAPH

Fig. 10. Typical Low Flow Hydrographs

When evaluating flow augmentation targets, the complementary and competitive aspects must be carefully examined as previously outlined in this chapter. The shape of the hydrograph is an important indicator of the potential value and extent of flow augmentation; however, each situation must be studied individually.

Selection of a minimum flow target is proposed in this report on the basis of economic efficiency. When target outputs are selected on this basis, shortages are usually greater and more frequent than allowed by current design standards (23). A simulation model could be used to indicate to water quality managers the loss in net benefits if a reduction in shortages appears desirable.

COMPARISON OF OPTIMUM WATER QUALITY OBJECTIVES WITH ACTUAL STANDARDS

To compare optimum conditions obtained from the analytical model and the simulation model, the Adopted Water Quality Standards, Willamette River and Multnomah Channel, Oregon State Sanitary Authority, February, 1967, (20), will be reproduced in part below.

"The following standards are based on a minimum gauged river flow of 5,500 cfs at Salem.

1. ORGANISMS OF THE COLIFORM GROUP (MPN or equivalent Millipore filter using a representative number of samples where associated with fecal sources). Average less than 1,000 per 100 ml with 20 percent of the samples not to exceed 2400 per 100 ml.

2. DISSOLVED OXYGEN
   No wastes shall be discharged and no activities shall be conducted which either alone or in combination with other wastes or activities will cause in the waters of the Multnomah Channel or the Willamette River.

   a) (Multnomah Channel and main stem Willamette River from mouth to the Willamette Falls at Oregon City, river mile 26.6.)
      D.O. concentration to be less than 5 mg/l

   b) (Main stem Willamette River from the Willamette Falls to Newberg, river mile 50.)
      D.O. concentration to be less than 7 mg/l

   c) (Main stem Willamette River from Newberg to Salem, river mile 85.)
      D.O. concentration to be less than 90 percent of saturation.

   d) (Main stem Willamette River from Salem to confluence of Coast and Middle Forks, river mile 187.)
      D.O. concentration to be less than 95 percent of saturation."

Minimum Flow Target at Salem. A slight discrepancy exists between the minimum flow of 5500 cfs used by the State Sanitary Authority (20) and 6000 cfs objective used by the Corps (25). In routing 30 years (1926 through 1955) of monthly historical flows through the authorized Willamette River system the Corps failed to meet their objective of 6000 cfs six times. Minimum routed flows were 4580 cfs, 4600 cfs, 4600 cfs, 4840 cfs, 5400 cfs, and 5895 cfs.

Although the simulation model indicated 6000 cfs was the optimum flow objective to maximize net benefits, the model failed to meet the objective seven times in 50 years. Minimum flows were 4710 cfs, 4720 cfs, 4790 cfs, 4800 cfs, 4830 cfs, 5815 cfs, and 5830 cfs. The flow objective of the State of Oregon appears more realistic in terms of reducing the frequency and magnitude of damages resulting from failures to meet water quality objectives caused by flows below the augmentation target.

Organisms of the Coliform Group. The results from the simulation model agree with the objective of the State.

Dissolved Oxygen. Dissolved oxygen profiles from Worley's (28) simulation of the response of the Willamette River to possible waste loadings indicate that the simulated results (16) would meet the State Standards with the possible slight exception of the lower reaches of the Newberg pool (part b).

Comparison of Degrees of Treatment Required.
"At least 85% removal of BOD and suspended solids removal plus effluent chlorination" (20) are required in the Willamette River Basin by the Oregon State Sanitary Authority. Degrees of treatment used in the simulation model were determined by nonlinear programming with the objective being the minimum cost of waste treatment. Input data were based on 1963 waste loadings and Willamette River responses during 1963 (4). If current or future waste loadings were used, the degrees of treatment would probably be very similar to current requirements.

SUMMARY

Particularly disturbing is the inability of the optimal system (in terms of economic efficiency) to provide additional water for flow augmentation during critical flow periods. During periods of very low flows, other water demands produce greater benefits than the release of water for flow augmentation. This situation could be expected in many basins with highly regulated flows, such as in the Willamette River Basin.

In a basin where a single reservoir regulates the downstream flow, the situation would not be as acute. Minimum flow objectives for fish enhancement below the proposed Holley Reservoir in the Calapooia River and the minimum conservation pool objective for temperature control were consistently met, with a few minor shortages (6 in 50 years) at optimum conditions. All of the shortages were only 5 percent or less of the target value.

Serious consideration should be given to the number and magnitude of shortages in actual projects. Proponents of systems analysis (13) claim this approach produces greater maximum net benefits than designs by action agencies using conventional design standards. The difference apparently stems from the fewer shortages allowed by current design standards. Action agencies are expected by society to control floods and meet irrigation contracts and power commitments. In view of the loss in utility caused by shortages and floods which are probably not accurately reflected by loss functions, current design standards are considered superior in the opinion of the Project Director.

The question still remains--at what frequency and magnitude do shortages become intolerable? This level varies with individuals and may be examined by the use of indifference curves and the concepts of utility resulting from a reduction in uncertainty (5). Subtracting the cost of uncertainty caused by shortages is one approach to evaluating alternative designs. A major contribution to this problem by systems analysis lies in the fact that simulation models can provide society with incremental costs and benefits associated with different designs and levels of shortages. From this additional information, society can select the design which offers a desired degree of security and sufficient returns from project expenditures.

SECTION 7

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Miss Linda Smith and Mrs. Gloria Uhri typed many drafts and the final copies of the papers and reports that were published from this project.

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SECTION 10

APPENDICES

I. Theory of Optimum Allocation of Water

II. Daily Streamflow Simulation

III. Recreation and Reservoir Operation

IV. Input Data

V. Flow Diagrams and Computer Programs

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APPENDIX I

THEORY OF OPTIMUM ALLOCATION OF WATER

Statement of the Problem

A technique is needed to aid planners, designers and operations personnel determine the optimum allocation of scarce water. During periods of high demands and low supplies of water, critical decisions must be made regarding how much water should be released and for what purposes, as well as how much should be stored for future releases or to be held to maintain a minimum pool. Water quality frequently deteriorates to extremely serious levels throughout water short periods. Frequently the only method readily available to maintain a suitable water quality for aquatic life and many other downstream beneficial uses is the release of stored water for water quality control.

Release of water for water quality control conflicts with demands for municipal and industrial water supplies, irrigation, head for hydroelectric power production, and reservoir fishing and recreational uses. Water stored for future releases will complement these competing demands until released. When released for water quality control, many downstream uses, including aquatic life, will be complemented or will benefit. Proposed in this report is an analytical model capable of identifying the extent and magnitude of the complementary and competitive aspects of water storage for water quality control.

Theory

Economists have used mathematical optimization techniques to study and explain the actions of a rational entrepreneur in their literature known as the "Theory of the Firm" (3). The entrepreneur's objective function may be to (1) maximize output subject to a budget constraint (2) minimize cost of production for a prescribed level of output or (3) maximize profits.

These same concepts can be applied to a river basin. To optimize water resources development or the economy within a basin or region, an institution must be functioning that is capable of regulating or controlling all pertinent actions within the system under consideration. In the United States such an institution is rare, but there are trends in this direction (4). Fortunately these optimization techniques can be applied to programs or even a specific project with a basin by careful definition of the system to be optimized.

To illustrate this flexible system concept, two examples will be briefly outlined. One system could consist of a completed project with all structural inputs (reservoir size and conveyance structures) fixed and all target outputs already determined (crops planted, generators intalled and municipalities connected to a distribution system). The critical decision is the allocation of available water. Another system could be

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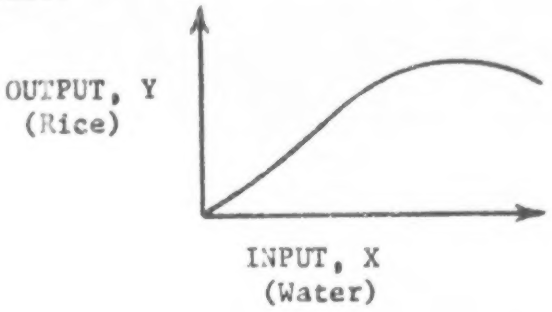
in the planning or design stages and neither the mangitude of the structural inputs nor the target outputs have been established. In either system, the operational decision is still the same--the allocation of water to maximize the objective function or minimize costs. The main difference is that the planning or design system has more decision variables and fewer constraints than an existing system.

Derivation

Economists define production as "any activity intended to convert resources of given forms and location into other resources of forms and locations deemed more useful for purposes of further production or consumption" (2). The term "location" is four dimensional, because in water resource development water must be available where and when needed. In any system the production or output is a function of an input or set of inputs. This relationship is described by a production function. In its simplest form the output, Y, is a function of an input X.

$$Y = f(X). \tag{1}$$

To illustrate this concept, let Y (output) represent the production of rice and X (input) represent water. If all other inputs, including water quality, are constant, then the production function shown in Figure 1 could result.



Simple Production Function

Fig. 1

Examination of Figure 1 reveals that points above the locus of points describing the production function are physically impossible and all points below the production function are inefficient.[1] Figure 1 also shows that excess water could result in a decrease in production.

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[1] For a certain amount of water applied during the growing season, there is a maximum output of rice when all other variables are held constant. Also, if this volume of water is applied during the growing season and the production of rice is less than the output indicated by the production function, then the water was used inefficiently.

This simple relationship can be expanded to be applicable to any water resource system. Rearrange equation 1 to

$$Y - f(X) = 0. \qquad (2)$$

The production function for any water resource system is now written in the implicit form and expanded to

$$H\ (Y_1, \ldots Y_s,\ X_1,\ X_2 \ldots X_n) = 0. \qquad (3)$$

where Y represents outputs (1, 2,...s) resulting from sufficient water of suitable quality being delivered when needed. X represents the n input variables which include structural, nonstructural, and operational input variables.

To simplify the notation, let $Y_{s+j} = X_j$ $(j = 1, 2 \ldots n)$

$$\therefore\ Y_{s+1} = -X_1,$$

$$Y_{s+2} = -X_2,$$

and $$Y_{s+n} = -X_n.$$

The production function may now be rewritten as

$$F(Y_1,\ Y_2, \ldots Y_m) = 0$$

where $$m = n+s$$

To maximize the net benefits of a water resource system, the objective function may be represented by the maximum net benefits,

$$\pi = \sum_{i=1}^{m} p_i Y_i \qquad (4)$$

where $$p_{s+j} = r_j \quad (j = 1,2,\ldots n).$$

The value p_i, normally representes the price or value of the outputs, Y, but in the implicit form used here, also represents the costs (r_j) of the inputs, X. In equation 4, the outputs contribute positive values to the objective function and inputs are negative terms.

The optimum combination of inputs and outputs is located on a response surface described by the production function. Therefore, the objective function is optimized subject to the production function contraint.

$$J = \sum_{i=1}^{m} p_i Y_i + \lambda F(Y_1,\ Y_2, \ldots, Y_m). \qquad (5)$$

The necessary or first-order conditions for maximization are

$$\frac{\partial J}{\partial Y_i} = p_i + \lambda F_i = 0 \qquad (i = 1,\ 2, \ldots m) \qquad (6)$$

where $F_i = \frac{\partial F}{\partial Y_i}$.

and $$\frac{\partial J}{\partial \lambda} = F(Y_1, Y_2, \ldots Y_m) = 0. \qquad (7)$$

A. Both Variables Outputs

To obtain a physical meaning for the nedessary conditions for maximization, select any two of the first m equations from equation 6 and obtain

$$\frac{P_j}{P_k} = \frac{F_j}{F_k} = \frac{-\partial Y_k}{\partial Y_j}, \quad (j,k = 1,2,\ldots m). \qquad (8)$$

The minus sign stems from the fact that if one output is increased, the other must be decreased.

If both variables are outputs (j and k both $\leq$ s) then equation 8 represents the relationship between all outputs of optimum conditons. Therefore, at optimum conditions, the rate of product transformation (RPT)[2] for every pair of outputs (holding the levels of all other outputs and inputs constant) must equal the ratio of their prices. For example

$$RPT_{jk} = \frac{MB_j}{MB_k} \quad \text{where} \quad RPT_{kj} = \frac{\partial Y_k}{\partial Y_j} \qquad (9)$$

In this example, at optimum conditions, if the inputs are held constant and one output is decreased an increment and the unused inputs transformed (applied) to increase another output an increment, then this rate of product transformation is equal to the ratio of the prices or value of the outputs.

This relationship can be visualized by examining equation 8. Assume the value or price of output j is low in comparision with k. At optimum conditions, a large increment of output j could be transformed into a small increment of output k. The loss in net benefits from reducing j would be equal to the increase in net benefits from increasing k. This relationship will hold for all pairs of benefits at optimum conditions and is sometimes referred to as "equating marginal benefits."

B. One Variable an Input and the Other an Output

Assume that the j th variable is an input and the k th variable remains an output.

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[2] The term rate of product transformation (RPT) is used because it is more descriptive than the commonly used marginal rate of transformation (MRT) and also because the use of marginal and rate in the same phrase is redundant (3).

Substitute $p_j = r_{j-s}$

where s = number of outputs

and $\partial Y_j = \partial X_{j-s}$

from $Y_{s+j} = -X_j$.

From equation 8 obtain

$$\frac{r_{j-s}}{p_k} = \frac{\partial Y_k}{\partial X_{j-s}}$$

or

$$r_{j-s} = p_k \frac{\partial Y_k}{\partial X_{j-s}} \qquad \begin{array}{l}(k = 1,2,\ldots s)\\ (j = s+1,\ldots,m).\end{array} \tag{10}$$

Equation 10 states that at optimum conditions the value of the marginal products (MP) of an input with respect to every output $(p_k \frac{\partial Y_k}{\partial X_{j-s}})$ must be equated to its cost. Therefore

$$MC_j = MB_k (MP)_{jk},$$

or

$$\frac{MC_j}{MB_k} = MP_{jk}. \tag{11}$$

The marginal product is the rate at which the Y_k output can be increased (or decreased) with respect to its inputs. Equation 11 states that at optimum conditions the cost of an incremental input X must be equal to the price or value of the resulting output Y. This relationship is sometimes known as "equating marginal benefits to marginal costs."

C. Both Variables Inputs

If both variables are inputs, then equation 8 can be written in the form

$$\frac{r_{j-s}}{r_{k-s}} = -\frac{\partial X_{k-s}}{\partial X_{j-s}} \tag{12}$$

where $(j, k = s + 1,\ldots n)$.

The minus sign reappears because at maximum conditions if one input is increased, then the other must be decreased. At optimum conditions, equation 12 indicates that the rate of technical substitution (RTS)[3] for every pair of inputs (holding the levels of all outputs and all other inputs constant) must equal the ratio of their prices,

$$RTS_{kj} = \frac{MC_j}{MC_k}. \tag{13}$$

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[3] The term rate of technical substitution (RTS) is used because it is more descriptive than the commonly used marginal rate of substitution (MRS) and also because the use of marginal and rate in the same phrase is redundant (3).

This relationship can be visualized by examining equation 12. At optimum conditions if all variables are held constant with the exception of two inputs, then the reduction in cost resulting from decreasing one input an increment must be equal to the cost of increasing or substituting the other input. This relationship is sometimes known as "equating marginal costs."

These conditions are the necessary or first-order conditions based on the theory of maximization of differential calculus. They were determined by setting the first partial derivatives equal to zero (equations 6 and 7). Solving these equations produces either maximum or minimum values for the response surface because the first partial derivative describes the slope of the response surface. (Fig. 2)

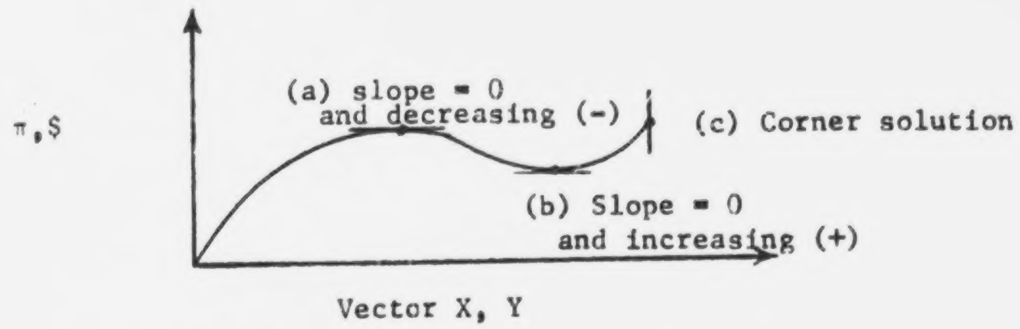

Fig. 2. Two-dimensional response surface.

In Figure 2, the necessary or first-order conditions would not indicate whether the results represented a maximum, such as (a), or a minimum, such as (b).

To differentiate between maxima and minima on a response surface (or points (a) and (b)) the sufficient or second-order conditions must be determined. These conditions reflect the change of the slope of the response surface. At maximum conditions the slope is decreasing (-), whereas at minimum conditions, the slope is increasing (+). Therefore, at maximum conditions the slope is decreasing or the sufficient or second-order conditions are negative.

The second-order conditions for the maximum net benefits require that the relevant bordered Hessian determinants alternate in sign:

$$\begin{vmatrix} \lambda F_{11} & \lambda F_{12} & F_1 \\ \lambda F_{21} & \lambda F_{22} & F_2 \\ F_1 & F_2 & 0 \end{vmatrix} > 0 ;\ldots.;(-1)^m \begin{vmatrix} \lambda F_{11}\cdots & \lambda F_{1m} & F_1 \\ \lambda F_{m1}\cdots & \lambda F_{mm} & F_m \\ F_1\cdots & F_m & 0 \end{vmatrix} > 0. \tag{14}$$

Multiplying the first two columns of the first array and the first m of the last by $1/\lambda$, and multiplying the last row of both arrays by λ,

$$\lambda \begin{vmatrix} F_{11} & F_{12} & F_1 \\ F_{21} & F_{22} & F_2 \\ F_1 & F_2 & 0 \end{vmatrix} > 0 \;;\ldots\ldots;(-1)^m \lambda^{m-1} \begin{vmatrix} F_{11} & F_{1m} & F_1 \\ \cdots & \cdots & \cdots \\ F_{m1} & F_{mm} & F_m \\ F_1 & F_m & 0 \end{vmatrix} > 0. \qquad (15)$$

Since $\lambda < 0$ from equation (6), the second order conditions require that

$$\begin{vmatrix} F_{11} & F_{12} & F_1 \\ F_{21} & F_{22} & F_2 \\ F_1 & F_2 & 0 \end{vmatrix} < 0 \;;\ldots\ldots; \begin{vmatrix} F_{11} & \cdots\cdots & F_{1m} & F_1 \\ \cdots & \cdots & \cdots & \cdots \\ F_{m1} & \cdots & F_{mm} & F_m \\ F_1 & \cdots\cdots & F_m & 0 \end{vmatrix} < 0. \qquad (16)$$

This derivation is based on the theory of maximization of differential calculus and therefore also is subject to the limitations of the theory. These shortcomings can be seen in Figure 2. The problem of differentiating between maxima and minima can be overcome by checking the sufficient conditions for maxima. Two other problems remain. When a maximum is located, it is difficult to determine whether it is the global maximum or possibly one of several local maxima. The other problem is that the maximum may be a "corner solution" (Point (C) on Figure 2). Corner solutions are found in economic problems because physical variables must be positive and also because of other constraints, such as budget or legal. Consequently, a solution may be at the maximum on a response surface and not meet the necessary conditions.

Application

To apply the preceding derivation to the optimization of water resources development equation 5 must be written in explicit mathematical terms,

$$J = \sum_{i=1}^{m} p_i Y_i + F(Y_1, Y_2, \ldots Ym). \qquad (5)$$

In equation (5) the objective is to maximize the net benefits ($\sum_{i=1}^{m}$) subject to the production function constraint $F(Y_1, Y_2, \ldots, Y_m)$.

To accomplish this feat the price or value of each of the outputs and costs of each of the inputs would have to be expressed mathematically. The price people are willing to pay for water depends on the amount available or supply and the cost of inputs varies with the amount needed or demanded. The magnitude of the inputs is a function of the water handled and the size of the target outputs depends upon consumer demand and the availability of sufficient water of suitable quality when needed. Streamflow is a stochastic process, consequently uncertainty is always involved regarding the allocation of volumes of water for beneficial uses. Finally demands and prices change seasonally. Obviously the task of expressing the situation in a water resource system is formidable.

To avoid some of these problems, researchers have developed simulation techniques to describe a water resource system (1, 4, 6, 8, 9). Simulation models attempt to generate stochastic process on high speed computers similar to events that could occur in nature. The models attempt to predict how proposed or existing systems might respond to the stochastic processes. Various structural inputs, target outputs, and operational procedures may be tested by the simulation model to approach a region on the response surface of optimum conditions.

Common mathematical searching techniques include the method of steepest ascent and other methods using incremental or marginal analysis (gradient techniques). These methods essentially change the inputs, outputs, or operational procedures by small increments, continuously trying to improve the objective function. The approaches normally will not locate an exact maximum (even if one existed) but produce a combination of inputs, outputs, and operational procedures within the limits of accuracy of the input data. A limitation of these searching techniques, similar to a limitation of differential calculus, is that it may be difficult to differentiate between local maxima and the global maximum.

A major advantage of simulation models is their ability to generate streamflows (stochastic processes) similar to what could occur in the future, because the sequence of flows is of vital importance to water users. In simulation models, it is easy to estimate the response of the system to different inputs, outputs, and operational procedures once a suitable simulation model has been developed and tested.

Early simulation models tended to use fixed operational procedures (7) due to the complexities involved. Naturally this shortcoming was recognized and numerous researchers delved into this area. Dynamic programming was applied by many, not only to develop operational procedures, but also to size inputs and target outputs. The number of computations using dynamic programming is high because of the iterative procedure of tracing many possible sequences.

Simple, realistic procedures for practicing engineers have not evolved because of the complexities of the complementary and competitive aspects of water storage and the understanding of higher mathematics required to comprehend and apply proposed techniques. The proposed Analytical Model (Section 3) proposes a simple, straightforward technique capable of identifying the extent and mangitude of the complementary and competitive aspects of water storage for water quality control. The model contains a step by step procedure for the allocation of scarce water to various beneficial uses which is essentially a rational searching procedure to identify the optimum conditions (Equations 9,11, and 13).

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APPENDIX II

DAILY STREAMFLOW SIMULATION

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DAILY STREAMFLOW SIMULATION

By Kip Payne,[1] W. R. Neuman,[2] A. M. ASCE, and
K. D. Kerri,[3] M. ASCE

INTRODUCTION

Daily streamflow simulation offers engineers an opportunity to study the response of water resource systems to synthetic daily flow traces. The regulation and routing of floods, and the release of water for water quality control and fisheries during low flow periods, can be of special interest. The objective herein is to develop a multiple-station daily streamflow generator capable of simulating daily flow sequences with frequency characteristics similar to those of the historical records. The hydrographs within each month are rearranged to reduce the variability of the recorded flows. Flows are simulated on the basis of the statistical parameters computed from the rearranged daily flows. The adequacy of the technique is tested by comparing the frequency distributions of the important statistical properties of the historical flows with those of the simulated flows.

Other Flow Simulators.—Halter and Miller (8)[4] developed a daily flow simulator using a linear regression model which generated 30 flows each month, on the basis of the mean monthly flow and the standard error of the monthly flow. The simulated hydrographs were not adequate because the serial correlation between previous flows was not incorporated in the generator, with the exception of recession curves. Flows followed a recession curve when a generated flow exceeded an assumed high flow value. Some of the variation between daily flows probably could have been reduced by using a variance computed from the flows within a month and also based on a function of the

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Note.—Discussion open until December 1, 1969. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, Vol. 95, No. HY4, July, 1969. Manuscript was submitted for review for possible publication on August 23, 1968.

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[4] Numerals in parentheses refer to corresponding items in the Appendix I.—References.

simulated monthly mean. Examination of historical records reveals that months with high flows usually exhibit a higher variation of flows within the month than months with low flows.

Beard (2) has developed a daily streamflow simulator for a single station. His model generates daily flows during the flood season using a second-order Markov chain and the frequency characteristics of the daily flows within a calendar month. Daily flows are adjusted to agree with the simulated monthly flows. The proposed simulator is an extension of a monthly simulator developed by Beard (3), but differs from Beard's daily model in two respects: (1) Historical hydrographs are rearranged; and (2) simulation of monthly flows are not necessary. Operational monthly flow generators have been developed and successfully tested by Thomas and Fiering (16), Harms and Campbell (10), Beard (3), and Fiering (5). Additional streamflow simulation methods have been proposed by Matalas (13), Quimpo (15) and Young and Pisano (19). Yevdjevich (18) has reviewed simulation models.

Arrangement of Data.—Daily flows during certain seasons are apt to be extremely variable. The variance computed for any particular day for a number of years is likely to be very high. If raw historical data for a season with highly stochastic flows were analyzed, the means would be similar, the variances high, and the regression and correlation coefficients low. Attempts to simulate flows from these statistical parameters would not produce hydrographs with statistical properties similar to historical ones, because the ascension and recession curves would not be simulated.

To preserve the ascension and recession curves of hydrographs, the historical flows should be rearranged prior to analysis. The procedure for rearrangement consists of the following steps:

1. Divide the annual flows into time spans of particular concern, depending on the use of the simulator. Appropriate time spans could be months or seasons.
2. Search the historical records of each time span and identify important hydrologic events, such as peak flows, minimum flows, or trends. During a flood month, the magnitude and number of flood or peak flows and the time between peaks are of extreme importance.
3. From an examination of important hydrologic events in each time span, determine the expected day or days of occurrence. Consideration also must be given to the expected time between events.
4. Rearrange the historical hydrographs around the peak or important expected day of the month. If a peak flow is expected on a certain day during a time span, then all historical peak flows for the time span should be rearranged around this day. As many of the ascension and recession curves of the historical hydrograph as possible should be rearranged around the peak day. The remaining segments of the hydrograph should be rearranged to preserve as great a portion of the historical hydrograph as possible. The same procedure is applied to minimum flows or trends.

Some streams may exhibit flow characteristics from two populations during a particular time span, such as a winter month with relatively steady, low flows during ice or snow conditions and fluctuating high flows during periods of heavy precipitation and runoff. Another possibility would be flows resulting from two sources, such as ground water and snowmelt. If two populations are distinct, they should be separated, if possible, and the simulator can then be programmed to generate flows from one population or the other, or both, based on the probability and characteristics of each event.

Development of Daily Flow Simulator.—The rearranged historical flows for each day usually are not normally distributed. The log-Pearson Type III method is used to generate flows because it is the recommended technique for determining flood flow frequencies (1,4). The step-by-step procedure for developing a daily flow generator is outlined in the following section. Beard has prepared detailed explanations of the analysis calculations (11), the synthesis procedure (12) and he has also developed computer programs to perform these operations.

ANALYSIS SECTION

Convert all rearranged flows, Q, to corresponding natural logarithms, L.

Calculate mean, M, standard deviation, S, and skew g for each day from the natural logs.

$$M = \frac{\sum_{h=1}^{N} L_h}{N} \quad \ldots\ldots\ldots \quad (1)$$

$$S^2 = \frac{\sum_{h=1}^{N} L_h^2 - \left(\sum_{h=1}^{N} L_h\right)^2 N}{N-1} \quad \ldots\ldots\ldots \quad (2)$$

$$g = \frac{N^2 \sum_{h=1}^{N} L_h^3 - 3N \sum_{h=1}^{N} L_h \sum_{h=1}^{N} L_h^2 + 2\left(\sum_{h=1}^{N} L_h\right)^3}{N(N-1)(N-2)S^3} \quad \ldots\ldots\ldots \quad (3)$$

in which N = the number of years of record; and Σ indicates the summation of all values (h) for a particular day.

Calculate a k (Pearson Type III standard deviate) value for each daily flow by subtracting the mean from the flow value and dividing by the standard deviation.

$$k_h = \frac{L_h - M}{S} \quad \ldots\ldots\ldots \quad (4)$$

Transform the k value to the normal standard deviate, X, using the skew coefficient and the Pearson Type III function by the following approximation:

$$X_h = \frac{6}{g}\left[\left(\frac{g}{2} k_h + 1\right)^{1/3} - 1\right] + \frac{g}{6} \quad \ldots\ldots\ldots \quad (5)$$

Treat these X values as variables and solve for the regression coefficients, the standard deviations for the variables, and the correlation coefficients (R) for each day.

$$X_{i,j} = \overset{(1)}{b}_{i,j}\, X_{i-1,j} + \overset{(2)}{b}_{i,j}\, X_{i,j-1} + \ldots\ldots \overset{(j)}{b}_{i,j}\, X_{i,1} \ldots\ldots\ldots \quad (6)$$

in which X = logarithm of the daily streamflow transformed to a normal standard deviate; b = regression coefficient; first subscript, i, represents the day number; the second subscript, j, represents the station number; and the superscript represents the independent variable number. A regression constant does not appear in the normalized form of the regression equation.

Convert the regression coefficients to beta coefficients, B, in which

$$\overset{(1)}{B}_{i,j} = \overset{(1)}{b}_{i,j}\, \frac{S_{i-1,j}}{S_{i,j}} \ldots\ldots\ldots \quad (7)$$

SIMULATOR SECTION

Simulation of flows begins with the generation of a random normal standard deviate, RN (mean zero and variance unity) as in the following equation

$$X_{i,j} = \overset{(1)}{B}_{i,j}\, X_{i-1,j} + \overset{(2)}{B}_{i,j}\, X_{i,j-1} + \ldots\ldots \overset{(j+1)}{B}_{i,j}\, X_{i,1} + (1 - R^2)^{0.5}\,(\mathrm{RN}) \quad (8)$$

in which R = the multiple correlation coefficient.

Convert the normal standard deviates, X, to Pearson Type III deviates, k, by the following approximation:

$$k = \frac{2}{g}\left\{\left[\frac{g}{6}\left(X - \frac{g}{6}\right) + 1\right]^3 - 1\right\} \ldots\ldots\ldots \quad (9)$$

This approximation is not correct under certain circumstances and must be checked with Fig. 1 to determine the value of k' in Eq. 10.

Calculate simulated flow, Q, in cubic feet per second.

$$\ln\,Q = M + \frac{k'S}{C} \ldots\ldots\ldots \quad (10)$$

or $Q = \exp\,[M + (k'S/C)]$ in which C = a coefficient depending on the stream,

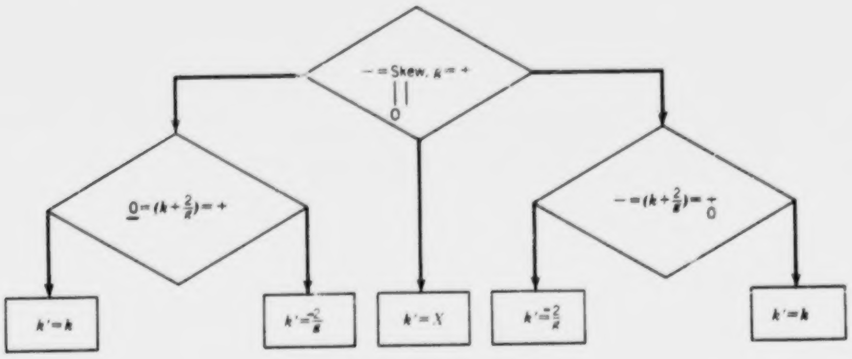

FIG. 1.—FLOW CHART FOR VALUES OF k'

the rearranged flows, and whether k' is positive or negative. This term is used to reduce any remaining excess variability in the simulated flows. A trend component could be incorporated in Eq. 10 if one were detected in the historical flows.

If today's simulated downstream flow is less than yesterday's simulated upstream flow, appropriate adjustments can be made by considering travel times and channel storage.

TEST BASIN

Description.—The proposed daily streamflow simulator was developed and tested using the flow records for two gaging stations on the Calapooia River, a tributary of the Willamette River in Oregon (Fig. 2). The headwaters of the Calapooia are located near the crest of the Cascade Mountains. Snow generally falls during the winter months and melts during the spring months. The stream travels through a rather narrow canyon from the headwaters, and then past a potential dam site at Holley, the upstream gaging station. Below Holley, the river enters the Willamette Valley at Brownsville. It then meanders across the flat Willamette Valley, until the river reaches its confluence with the Willamette River at Albany. The downstream gaging station is located three miles above the mouth.

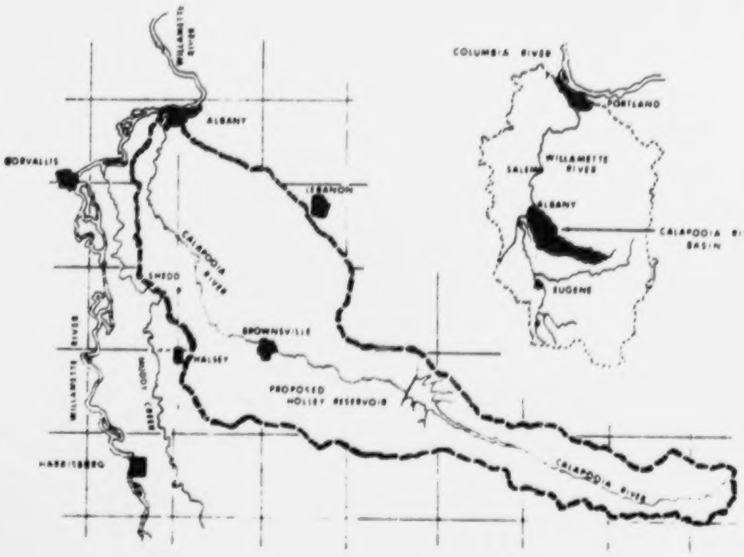
WILLAMETTE RIVER
ALBANY
CORVALLIS
LEBANON
CALAPOOIA RIVER
SHEDD
BROWNSVILLE
HALSEY
PROPOSED HOLLEY RESERVOIR
WILLAMETTE RIVER
MUDDY CREEK
HARRISBURG
CALAPOOIA RIVER
COLUMBIA RIVER
PORTLAND
SALEM
WILLAMETTE RIVER
ALBANY
CALAPOOIA RIVER BASIN
EUGENE

FIG. 2.—CALAPOOIA RIVER BASIN

The Calapooia River, which is fed by snowmelt and runoff from rainfall, could be described as a typical stream on the western slopes of the Cascade Mountains in the Pacific Northwest. The flow is influenced by rainfall from winter storms which can cause short duration floods. Sometimes, runoff from a rain will be accompanied by high flows from melting snows. During early spring, runoff is high due to melting snow. Flows gradually decrease throughout the summer, and gradually increase during the fall as storm activity increases. Peak flows of short duration are observed during the fall and spring when a rain storm passes over the basin.

Arrangement of Data.—Historical flows were rearranged in accordance with the procedures outlined previously. Monthly time spans were selected because these time periods appeared to group similar important hydrologic events.

Thus, the procedure for rearranging the historical flows depended on the month under consideration. For a particular month, the days which exhibited peak flows were recorded for each year of historical record. In the fall, the months frequently displayed one peak near the end of the month. Winter months usually had two or three peak flows, while spring months generally had one peak early in the month. During the summer the flows gradually decreased throughout the month, because the stream was fed by snowmelt.

To rearrange the flows during a particular month, one or more days were selected as the peak, and all historical flows were rearranged about it. For example, the average peak day in November occurred on the 23rd, and most Novembers experienced only one storm producing a significant peak. The flows for every November of record were rearranged with the peak flow on the 23rd. The flow sequences of the original hydrograph were maintained, as closely as possible, with special priority given the ascension and recession curves. This procedure was repeated for the spring.

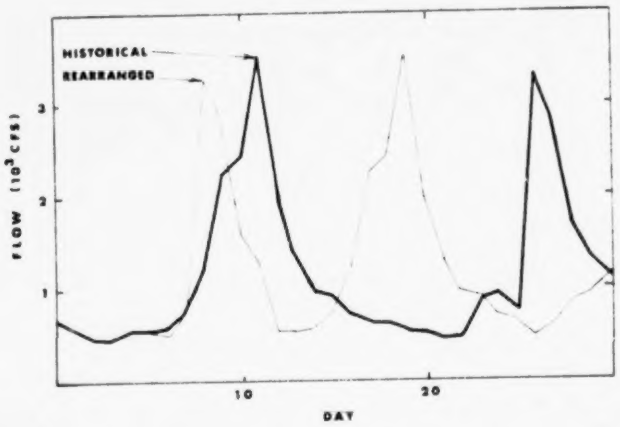

FIG. 3.—TYPICAL JANUARY HISTORICAL HYDROGRAPH AND SAME HYDROGRAPH REARRANGED ABOUT PEAK DAYS FOR ANALYSIS

Winter months having two significant peak flows, naturally had both the highest and next to highest peak flows occurring around the fifteenth of the month, on the average. This unrealistic event was eliminated by calculating the average time between peak flows. For example, in January the average time between peak flows was 11 days; therefore, the highest peaks were rearranged around the 20th day of the month and the next to highest peaks rearranged around the ninth of the month. Fig. 3 shows a typical historical flow and the resultant rearranged flow.

During the summer months, the flows gradually decreased throughout each month, except when a few, scattered storms occurred. Since not many peak flows occurred, the summer flows were not rearranged.

Development of Daily Flow Simulator.—The rearranged historical flows for each day were not normally distributed. In an attempt to transform the rearranged flows to normal distributions, two transformations were examined. Both a natural log and a normal standard deviate, based on a Pearson Type III function transformation, were studied. A chi-squared goodness of fit test was used to test for the normality of the transformed flows. The transformations both apparently followed the normal distribution, at the 5% level of significance. Therefore, the use of the log-Pearson Type III method is justified.

A trend component was not incorporated into Eq. 10, because none was detected in the historical flows. Summer flows were decreasing at the downstream station due to increased irrigation activity, but the natural flows were reconstructed (17).

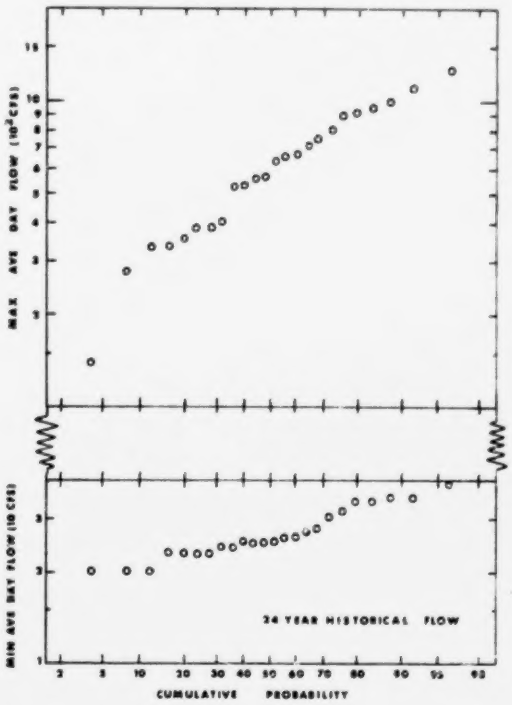

FIG. 4.—PLOT OF MAXIMUM AND MINIMUM AVERAGE DAILY HISTORICAL FLOWS ON LOG PROBABILITY PAPER, UPSTREAM STATION

Approximately once a year the simulated downstream flow was slightly less than the previous day's upstream flow. On these occasions, the downstream flow was set equal to the upstream flow, because the travel time between the stations was one day.

Test of Model.—To test a flow simulator, two questions must be answered: (1) What tests should be used; and (2) how is it decided whether or not the statistical distributions of the flows generated are close enough to historical distributions? The tests used to examine the similarity between historical and generated flows were comparisons of statistical parameters. These parameters reflected important flow sequences, from the standpoint of operating the water resource system and of the beneficial uses served by the system. The daily flow generator was deemed sufficient, when plots of the simulated data approximated those of the historical records. Important parameters selected included the distribution of annual mean flow, maximum

TABLE 1.—FINAL *C* VALUES

Deviation, k' (1)	Upstream (2)	Downstream (3)
Negative	1.35	1.45
Positive	1.1	1.2

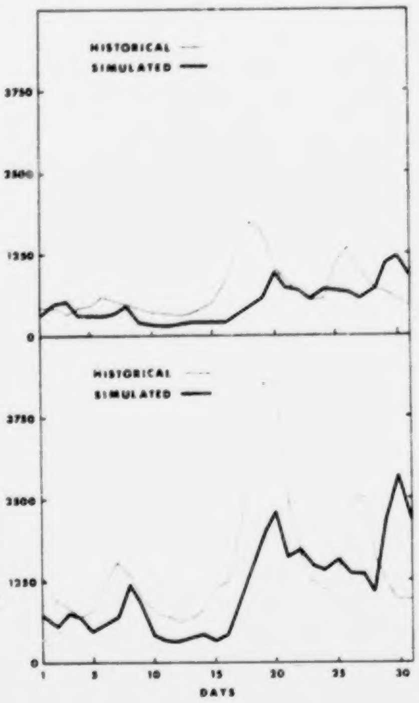

FIG. 5.—TYPICAL JANUARY HISTORICAL AND SIMULATED FLOWS

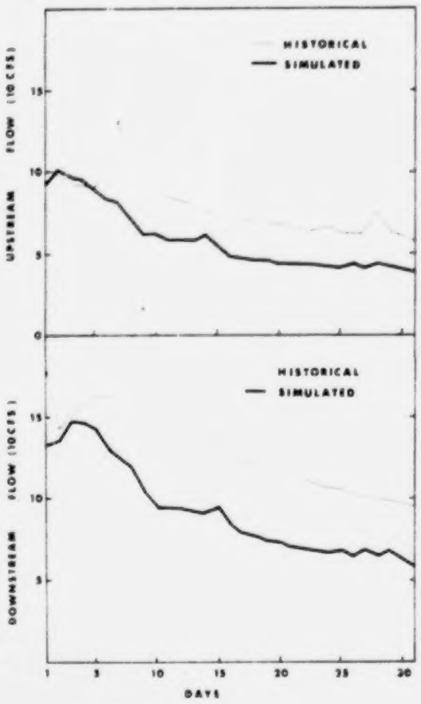

FIG. 6.—TYPICAL JULY HISTORICAL AND SIMULATED FLOWS

and minimum daily flows, maximum three-day average flow, minimum seven-day average flow, and minimum average summer flow (June, July, August, and September). These properties were plotted on normal, log, and extremal probability papers. All of them plotted closest to a straight line (Fig. 4) on log-probability paper. Originally, the analysis of the generated flows revealed that the distribution of the annual mean flow was successfully retained, but the simulated maximum and minimum daily flows exhibited greater variation than the historical flows, i.e., higher maximums and lower minimums. To reduce these variations, the coefficient C in Eq. 10 was introduced.

After an initial trial, the distribution of the simulated maximum flows corresponded closely to historical ones, but the simulated minimum flows remained slightly low. To correct this situation, two different C values were selected for each station, and the value applied depended on whether the term containing the deviation (k' in Eq. 10) was added to, or subtracted from, the rearranged mean of the log of the historic flow. The final C values are shown in Table 1.

TABLE 2.—SUMMARY OF EXTREME VALUES OF HISTORICAL AND SIMULATED FLOWS, UPSTREAM STATION, IN CUBIC FEET PER SECOND[a]

Run (1)	Maximum 1-day (2)	Maximum 3-day (3)	Maximum 10-day (4)	Minimum 1-day (5)	Minimum 7-day (6)	Minimum 30-day (7)	Minimum 120-day (8)	Annual average (9)
1	13,460	10,460	5,866	18.7	24.0	26.8	47.4	471.6
2	12,050	8,820	5,490	15.0	19.8	26.5	47.5	469.3
3	15,340	10,760	6,710	16.4	21.4	27.3^{b}	42.8	487.4
4	9,380^{c}	6,230^{c}	3,456^{c}	14.0	21.6	25.5	48.1^{b}	457.7
5	15,600	10,890	5,941	10.9	17.5	25.5	43.5	455.5
6	12,490	10,360	5,850	12.7	18.1	22.2	47.1	454.2^{c}
7	10,250	7,060	5,169	18.3	24.0	24.2	39.1	497.4^{b}
8	14,490	10,180	5,849	8.2^{c}	11.9^{c}	18.6^{c}	34.2	480.6
9	18,670^{b}	14,140^{b}	7,585^{b}	11.5	15.7	22.4	44.9	478.7
10	15,200	11,560	6,394	19.3	24.5^{b}	23.9	41.5	468.4
Historical	11,000	8,830	5,487	20.0^{b}	24.0	22.8	32.5^{c}	465.8

[a] N = 24 for all runs and historical record; Upstream $(-k')\ \frac{k'S}{1.35}$, $(+k')\ \frac{k'S}{1.1}$: Downstream $(-k')\ \frac{k'S}{1.45}$, $(+k')\ \frac{k'S}{1.2}$.
[b] Maximum.
[c] Minimum.

TABLE 3.—SUMMARY OF EXTREME VALUES OF HISTORICAL AND SIMULATED FLOWS, DOWNSTREAM STATION, IN CUBIC FEET PER SECOND[a]

Simulation run (1)	Maximum 1-day (2)	Maximum 3-day (3)	Maximum 10-day (4)	Minimum 1-day (5)	Minimum 7-day (6)	Minimum 30-day (7)	Minimum 120-day (8)	Annual average (9)
1	27,400	22,140	15,550	21.8	32.1^{b}	34.3	67.2^{b}	982.3
2	34,990	29,090	19,440	17.6	27.3	34.6	61.3	986.6
3	29,800	24,070	18,530	18.8	26.0	35.1^{b}	65.4	1,015.0
4	28,800	18,990^{c}	10,430^{c}	18.7	27.9	32.1	64.6	949.5
5	42,130	33,210	17,870	11.2	23.0	31.4	63.0	941.6^{c}
6	44,180^{b}	36,840^{b}	20,940^{b}	5.6^{c}	23.0	27.9	64.4	949.3
7	28,910	24,360	14,670	21.0	29.1	30.2	53.7	1,068.0^{b}
8	34,010	26,760	13,360	11.4	15.3^{c}	23.5^{c}	45.4	1,019.3
9	31,660	29,930	16,570	15.1	19.9	28.7	64.4	1,000.3
10	32,310	26,660	15,950	24.1^{b}	29.7	29.9	60.6	978.3
Historical	26,800^{c}	21,970	13,880	11.0	27.7	26.5	42.9^{c}	949.4

[a] N = 24 for all runs and historical record; Upstream $(-k')\ \frac{k'S}{1.35}$, $(+k')\ \frac{k'S}{1.1}$: Downstream $(-k')\ \frac{k'S}{1.45}$, $(+k')\ \frac{k'S}{1.2}$
[b] Maximum.
[c] Minimum.

Results.—Typical simulated and historical flows for the upstream and downstream stations for a winter month and a summer month are shown in Figs. 5 and 6. The generated flows at both stations appear similar to the historical hydrographs with respect to smoothness between daily flows, randomness in reductions and increases in the flow rate. Fig. 6 indicates the ability of the simulator to generate a dry July. The relationships between the daily means of the rearranged flows and typical historical and simulated wet flows can be examined in Fig. 7.

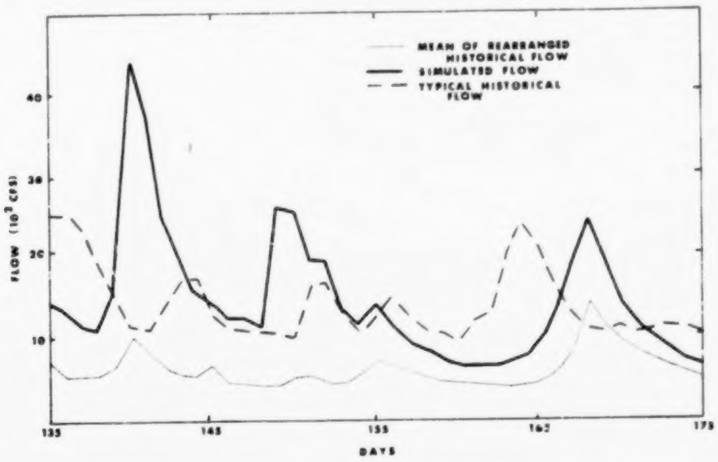

FIG. 7.—PLOT OF DAILY MEAN FOR REARRANGED FLOWS AND TYPICAL HYDROGRAPHS FOR HISTORICAL AND SIMULATED WET FLOWS

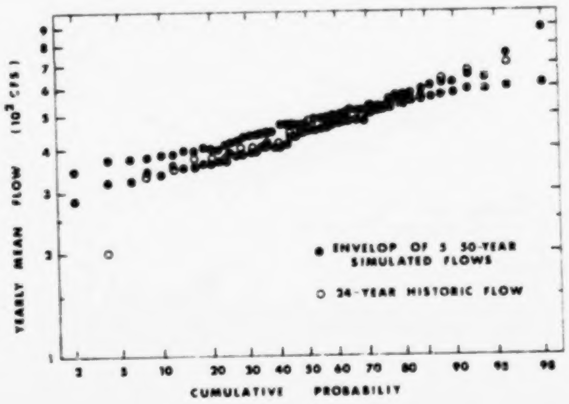

FIG. 8.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MEAN ANNUAL FLOWS, UPSTREAM STATION

Comparisons of the distributions of the parameters of the simulated flows with the historical flows are shown in Figs. 9 through 14 and Tables 2 and 3. Five 50-yr sequences were generated and compared with the 24 yr of historical record. Figs. 8 and 9 show that the envelopes of the simulated annual mean flows at both stations, agreed very closely with the historical annual mean

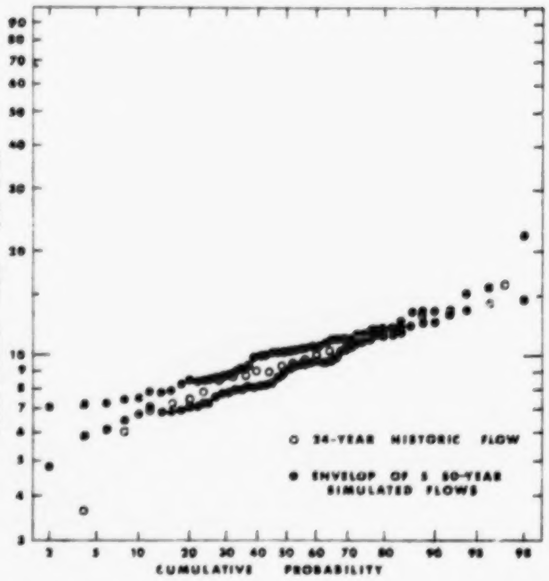

FIG. 9.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MEAN ANNUAL FLOWS, DOWNSTREAM STATION

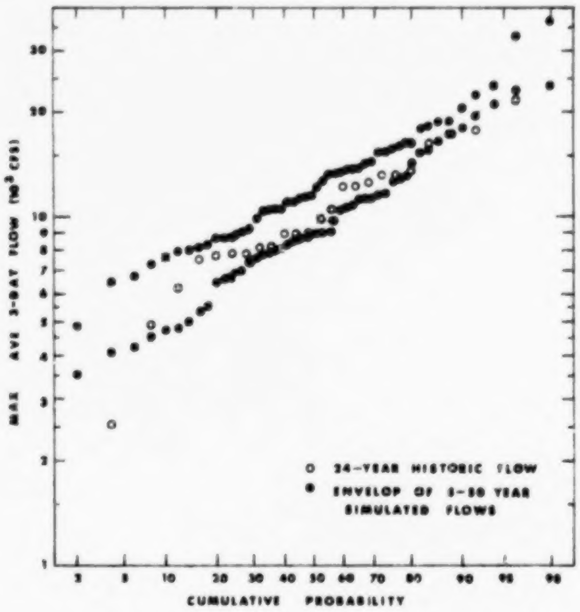

FIG. 10.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MAXIMUM AVERAGE THREE-DAY FLOWS, DOWNSTREAM STATION

flows. The maximum average days at both stations were distributed similar to the historical maximum average daily flows. Figs. 10 and 11 indicate that the historical maximum 3-day and 10-day average flows are contained within the envelopes of the five 50-yr simulated values. The minimum one-day (Fig. 12), 7-day (Fig. 13), and 30-day historical flows for both stations were fairly well contained within the five 50-yr simulated flows.

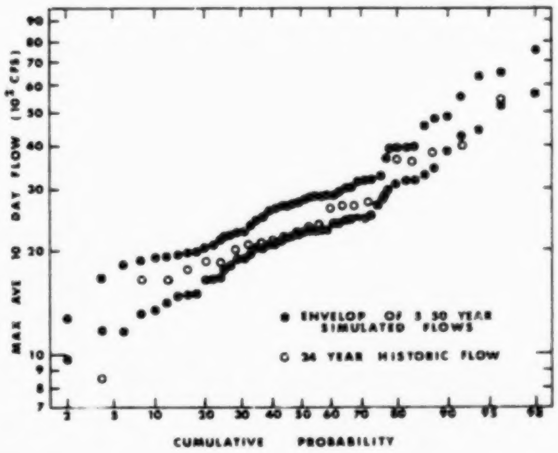

FIG. 11.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MAXIMUM AVERAGE TEN-DAY FLOWS, UPSTREAM STATION

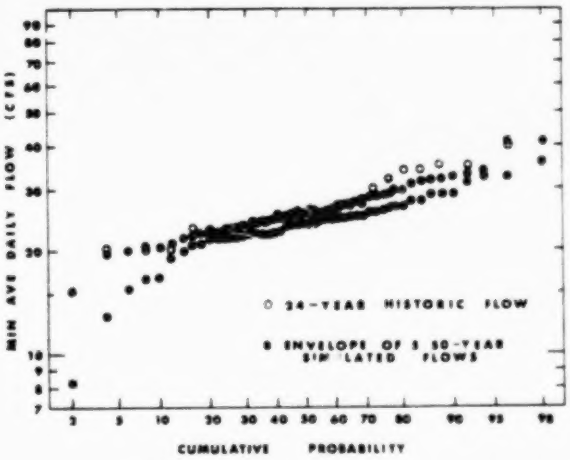

FIG. 12.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MINIMUM AVERAGE DAILY FLOWS, UPSTREAM STATION

The distributions of the 120-day summer flows were slightly flatter (Fig. 14), indicating that the extremes were not as great as the historical, possibly due to some loss of monthly correlation. However, correlation between spring (March, April, May) and summer (June, July, August, September) runoff was greater for the simulated flows than the historical flows ($R = 0.412$ versus $R = 0.162$ for $N = 25$ and $N = 29$ respectively, for the upstream station), which can be attributed, in part, to the rearrangement. Fig. 7 also illustrates the ability of the simulator to retain monthly flow properties. If a significant loss of monthly correlation was evident, a monthly simulator could be used to generate monthly flows, and the generated daily flows could be adjusted accordingly. The same procedure could be extended to annual correlations (10). Tables 2 and 3 reveal the numerical relationships between simulated and historical maximum and minimum flows for both stations. Historical records were available for 24 yr for both stations, and a simulation run was divided into 24 yr periods. In most cases, the historical values were contained within the range of the generated flows.

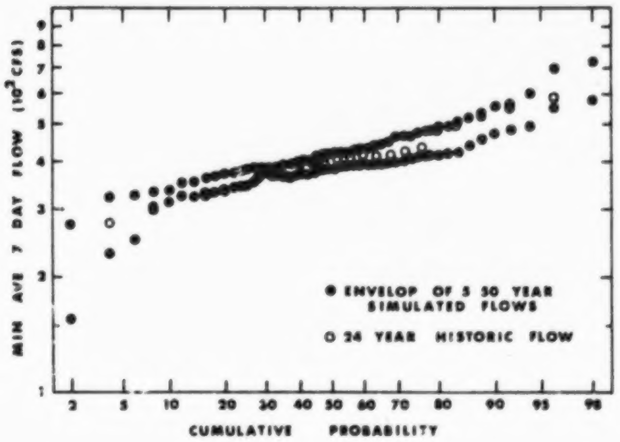

FIG. 13.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MINIMUM AVERAGE SEVEN-DAY FLOWS, DOWNSTREAM STATION

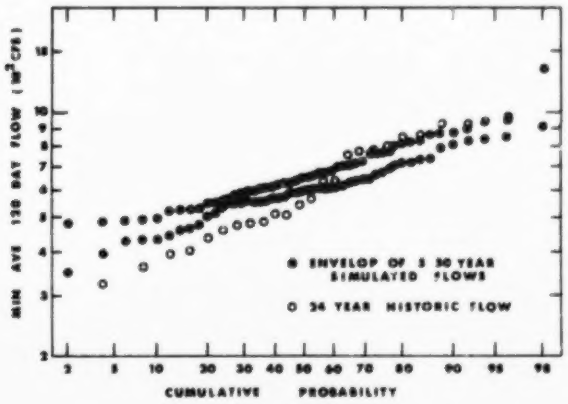

FIG. 14.—DISTRIBUTIONS OF HISTORICAL AND SIMULATED MINIMUM AVERAGE 120-DAY FLOWS, UPSTREAM STATION

EXAMINATION OF DATA

A valid question is, what would have been the results if raw, historical flows had been analyzed and simulated, instead of the rearranged flows? In the test basin, the low flows were not rearranged; consequently, the simulated minimum flows would be the same. Fig. 15 shows the difference in the statistical parameters of the raw and rearranged flows for January, a month with highly stochastic flows.

Simulation of five 50-yr periods, using the results of the analysis of the raw historical records and the final C coefficients, reproduce a distribution of annual flows very similar to Figs. 8 and 9. The maximum average daily flows plotted considerably below the historical flows, but the slope was similar. When the length of the time span for the maximum average flow increased (3 days and 10 days), the simulated flows approached the historical flows, but the slope of the plotted flows became steeper. Therefore, to preserve the distributions of the maximum flows when simulating the daily flows in the test basin, it is necessary to rearrange the raw historical flows in a manner that will preserve the ascension and recession curves of the hydrographs.

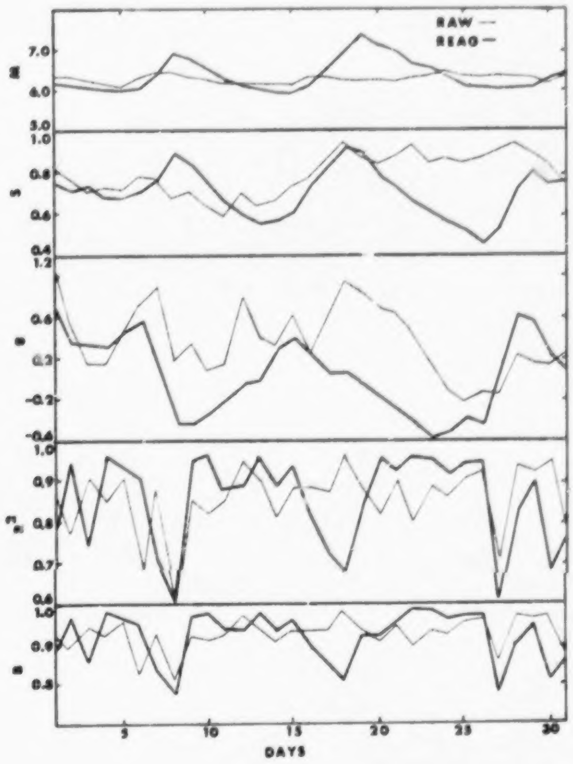

FIG. 15.—COMPARISON OF STATISTICAL PARAMETERS FOR RAW AND REARRANGED HISTORICAL FLOWS FOR JANUARY, UPSTREAM STATION

As in most simulation models, this one requires considerable time to prepare the input data, this primarily involves the conversion of recorded daily flows to a form for computer input. The rearranging of historical flows, analysis of these flows, the flow simulation, and the analysis of the simulated flows can be accomplished by computers. The selection of C coefficients to adjust the simulated flows to historical flows, is a limitation of this approach. Different people might select different C values from the same data. Other problems common to most simulation models of this type include errors in measuring observed flows and random sampling errors resulting from short records of historical flows.

To reduce the variability of the daily flows, coefficient C was introduced in Eq. 10. Consequently, this adjustment is not reflected to other stations or subsequent time periods. If the simulated normal standard deviate ($X_{i,j}$, Eq. 8) was adjusted, then this regulation would be reflected in other stations and later time periods. Adjustments in the simulated flows were applied in Eq. 10, because this was the easiest location to alter the flows so that flows with statistical distributions similar to historical flows could be produced.

Adverse, potential flow sequences are easily simulated by the proposed model. If greater variability than historical flows are determined desirable to investigate, the C value can be reduced. This procedure would allow the study of the response of a design under consideration, to extremely high and low flows. If the historical data were suspected of representing abnormally wet or dry years, the simulated flows could be appropriately increased or decreased and again the response of different plans or designs could be scrutinized.

Daily streamflow generators have been written in FORTRAN and DYNAMO, a simulation language (6), (7), (14). Most computers readily handle FORTRAN, but the generator was more difficult to debug in comparison with DYNAMO. DYNAMO is adaptable only to certain computers, and the program requires considerable talent to be made operational on any computer. In contrast to FORTRAN, the DYNAMO language was written for simulation, and programs are very easy to debug because of the checking capabilities incorporated in the DYNAMO program. FORTRAN compilers are too laconic for efficient debugging for many programmers. DYNAMO's limitations include an inability to store large amounts of data and to use exogenous data. FORTRAN programs apparently can handle larger or more complicated basins; however, DYNAMO has been used in a study of the Susquehanna River Basin (9). The cost of simulation by either language seems to be a function of the computer on which they are used, rather than any discernable differences in operating efficiencies. The computer time to simulate and analyze the simulated flows for a 250-yr period, required approximately 7-minutes on a Control Data Corp. (CDC) 6600 computer.

Other streams were not simulated by the proposed generator, because of its empirical nature. The writers believe that most unregulated streams can be simulated by the methods proposed. Recent developments in computer technology that allow visualization of results, virtually permit engineers to converse with computers, and C values (Eq. 10) can be quickly adjusted or examined to the satisfaction of the user.

CONCLUSION

A daily multistation streamflow simulator has been proposed which is capable of generating both nonhistoric flow sequences with statistical properties and also hydrographs similar to historical flows. Planners, designers, managers, and operations personnel have a tool which can help them analyze the response of proposed and existing water-resources systems to potential, nonhistorical flow sequences of longer duration than historical records.

ACKNOWLEDGMENTS

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APPENDIX II.—NOTATION

The following symbols are used in this paper:

B = Beta coefficient of regression equation;
b = regression coefficient;
C = dampening constant, depends on sign of k';
g = skew of natural logs of flow;
h = annual subscript for natural log of flow for a particular day;
i = time subscript (day);
j = station subscript;
k = difference between natural log of flow and mean divided by standard deviation (Pearson Type III standard deviate);
k' = adjusted k value depending on magnitude of skew, g;
L = natural logarithm of flow;
M = Mean of natural logs of flow;
N = number of years of record;
Q = rearranged natural flow;
R = multiple correlation coefficient;
RN = random normal standard deviate;
S = standard deviation of natural logs of flow;
X = normal standard deviate; and
Σ = summation of all values for a particular day.

APPENDIX III

RECREATION AND RESERVOIR OPERATION

Introduction

Water resource developers and recreation planners are confronted with a conflict between the beneficial use of water impounded in reservoirs for reservoir recreation or for release for downstream purposes, such as water quality control and irrigation. To develop benefit functions for recreation associated with a reservoir, the response of recreational attendance caused by reservoir operation should be known.

Hufschmidt and Fiering (3) and the Outdoor Recreation Resources Review Commission Study Report No. 10 (6) both stress the urgent need for information revealing the response of recreational attendance to reservoir fluctuations. Ullman (5) has indicated the need for statistical analysis to demonstrate the influence of reservoir fluctuation on recreation. This appendix reports findings of a study of Folsom, Isabella, Millerton, Whiskeytown and Shasta Reservoirs in California. Unfortunately, only Folsom Reservoir provided sufficient, accurate data to report results with a degree of statistical confidence.

Numerous factors are known to contribute to the recreation attendance of a reservoir in addition to fluctuations in the surface level. Climate, topography, vegetative cover, water quality, and other environmental influences also affect attendance. The type of recreation, the proximity of population centers, and the availability of alternatives are also important. Discussions of the factors that influence attendance are available in work by others (1, 3, 5, 6).

Observations

Current opinion on the influence of reservoir operation on reservoir attendance for recreational purposes is based apparently on personal observations. The ORRRC Study Report 10 (6) states that "the fact that at low stages an unsightly, often muddy and trash-littered shoreline is exposed apparently does not appreciably decrease the number of people who come to enjoy the water." The Report points out that the quality of the recreational experience is decreased because of the lowering of the surface level.

The TVA (4) has observed that it is not clear the extent to which surface fluctuations influence attendance. TVA notes that other factors also influence recreation and that water skiers and boaters appear not to be bothered too much by reservoir fluctuations.

Considerable insight regarding the influence of reservoir operation on recreation can be obtained from examining data from Whiskeytown Reservoir. During its first recreational season the surface only fluctuated approximately one foot in order to maintain the optimum head on a hydroelectric power plant. Attendance was high early in May when fishing season opened. It decreased and then increased when the weather warmed in June and then continuously decreased during the latter part of July and August. This latter decrease could have been caused by the required drive in a hot car from population centers to the reservoir, thus a reducation in the quality of the experience. An increase in attendance was recorded during the Labor Day week end.

The reservoir surface level at Isabella increased during the spring to a maximum during June and then continuously decreased during the remainder of the recreational season. Monthly attendance figures produced distribution curves similar to monthly Whiskeytown data and probably for the same reasons.

Observations on Shasta Lake indicate that attendance figures drop after a year when the level is unusually low. Evidently people plan to enjoy their summer vacation at Shasta and if the level is low, many do not return the following year.

Folsom Reservoir

Folsom Reservoir is located approximately 20 miles east of Sacramento, California. During the recreational season, from the third week end in May through the third week end in September, the reservoir surface has fluctuated from the maximum operating surface at elevation 466 (surface area, 11,500 acres) to elevation 390 (surface area, 6,180 acres) during the operating period from 1958 to 1965. In the spring the reservoir fills and reaches a peak pool around the middle of June. The surface then gradually recedes throughout the remainder of the recreation season. Figure 1 depicts the level-duration diagram for Folsom Reservoir.

To furnish an indication of the recreational environment at Folsom Reservoir, the results of an evaluation by the California Department of Parks and Recreation (1) is presented in Table I. The point system employed was developed by the Department to estimate the value of recreation benefits.

Surface water quality samples during the recreational season near Granite Bay yielded ranges of temperature from 22 to 26°C and dissolved oxygen from 7 to 9 mg/l. The pH was usually slightly above 7 and the water was clear (one turbidity reading of 98% light transmission).

An indication of the magnitude of the use of the entire Folsom Lake State Recreation Area is the fact that during fiscal 1965-66, 4,667,199 visitor-days were recorded in comparison with 1,817,000 visitor-days at Yosemite National Park.

Accurate attendance counts, in terms of the number of automobiles, are available for week ends during the recreation season at the Granite Bay checking station. People use the Granite Bay area primarily for

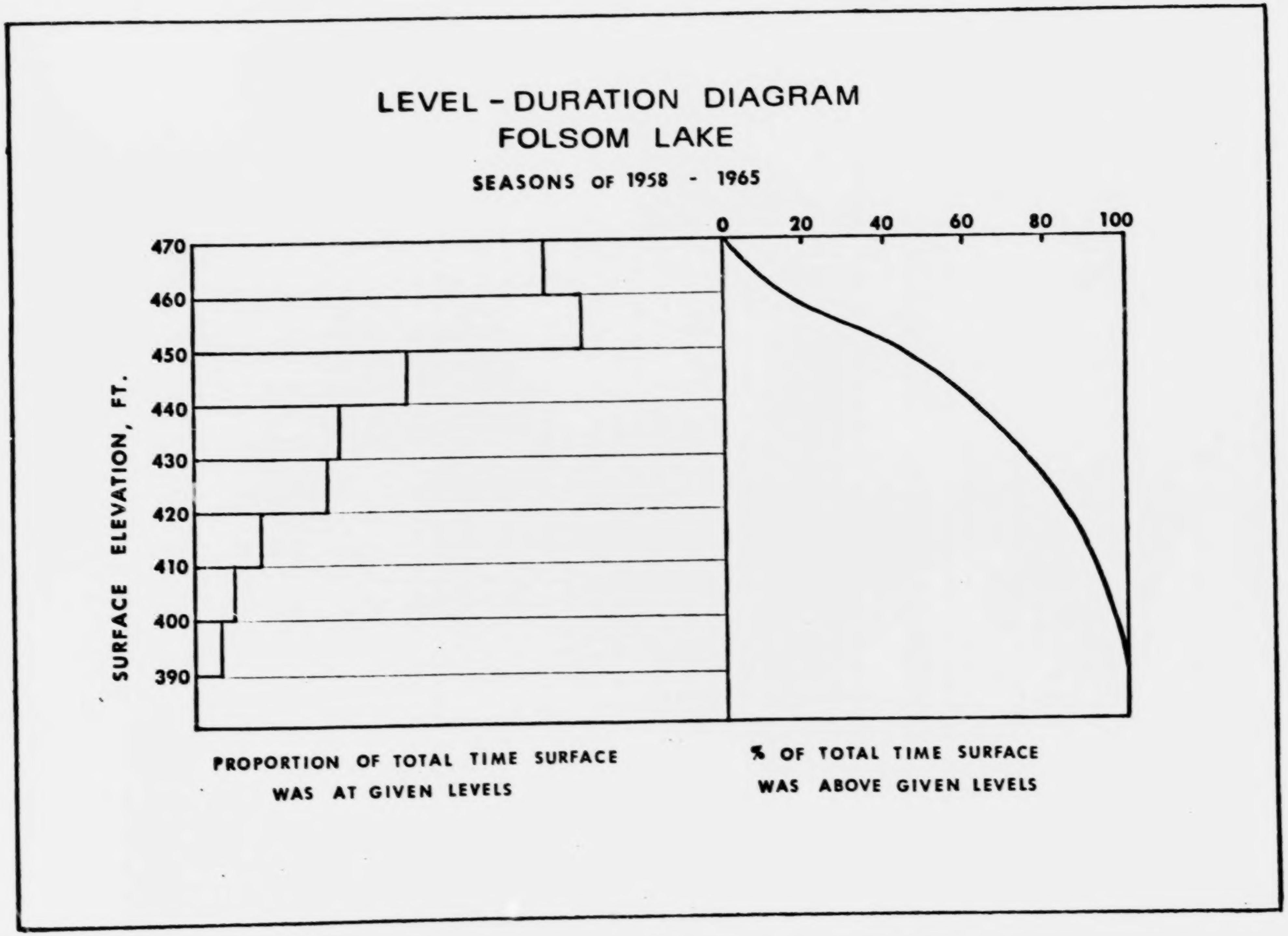

FIGURE 1. LEVEL-DURATION DIAGRAM FOR FOLSOM RESERVOIR

TABLE I. DESCRIPTION OF RECREATION ENVIRONMENT
AT FOLSOM RESERVOIR (1)

VALUE POINTS

Factor	Maximum Points	Folsom Reservoir
Reservoir Operations	20	13
Location of Site	30	19.6
Variety and Quality of Recreation	30	24.3
Esthetic Qualities of Site	20	13
Total	100	70 (rounded)

DOLLAR EVALUATION

Basic Value	Value Points	Total Value
$ 0.50	70	$ 1.20

launching boats and swimming. Good access is provided to all facilities. The launch ramps are paved and well maintained and are satisfactory until the pool drops below elevation 403. Well developed accommodations are maintained in the swimming area, with adequate parking and picnicking space and modern comfort stations. Figure 2 shows the beach (slope approx. 4.5%) and shade trees in the picnic area.

Attendance data in terms of automobile counts was converted to visitor-days by multiplying the number of automobiles by four. The third week end in May, June, July, August, and September and Labor Day week end provided sample data for this investigation. The monthly week ends were selected in an attempt to avoid any bias which might be created by three or four-day week ends caused by Memorial Day or July Fourth. Labor Day week end was included because it is always a three-day week end and would allow the opportunity to observe attendance on a holiday. To compare Labor Day with the other week ends, attendance figures were multiplied by two-thirds.

Population changes in the area served by Folsom Reservoir were accounted for by dividing attendance values by the population of Sacramento County during the year they were recorded (Equation 1). This approach transformed recorded values into dimensionless expressions of attendance that would relate each year to a common base. Figure 3 illustrates the relationship between adjusted attendance and the beach length, measured from the high water line to the water surface.

$$\text{Adjusted Attendance} = \frac{\text{Recorded Attendance}}{\text{County Population During Year Recorded}} \qquad (1)$$

Variables considered influencing attendance at Folsom Reservoir in this statistical analysis included reservoir operation, temperature, wind, and time of year. Reservoir operation can be measured by a change in reservoir surface level, surface area, or length of beach. This study used the slope distance from the high water mark, which coincided with the location of shade, picnic facilities, and comfort stations, to the existing water line. This distance was considered the most accurate description of the influence of reservoir operation on the recreational experience at Granite Bay on Folsom Reservoir.

Regression analysis was performed on the data to determine if statistically significant relationships (test hypothesis $\beta = 0$) and correlations existed between attendance and the other measured variables. Results of the analyses are summarized in Tables II and III (2). All data were used to compute the results in the entire season row.

Simple regression analysis revealed that no statistically significant relationship existed between wind and attendance at Folsom Reservoir with the exception of Labor Day week end. The maximum wind recorded during the study period was 25 mph and it is highly probable that areas experiencing high winds could expect a significant reduction in attendance during windy periods.

Fig. 2. Granite Bay Recreation Area

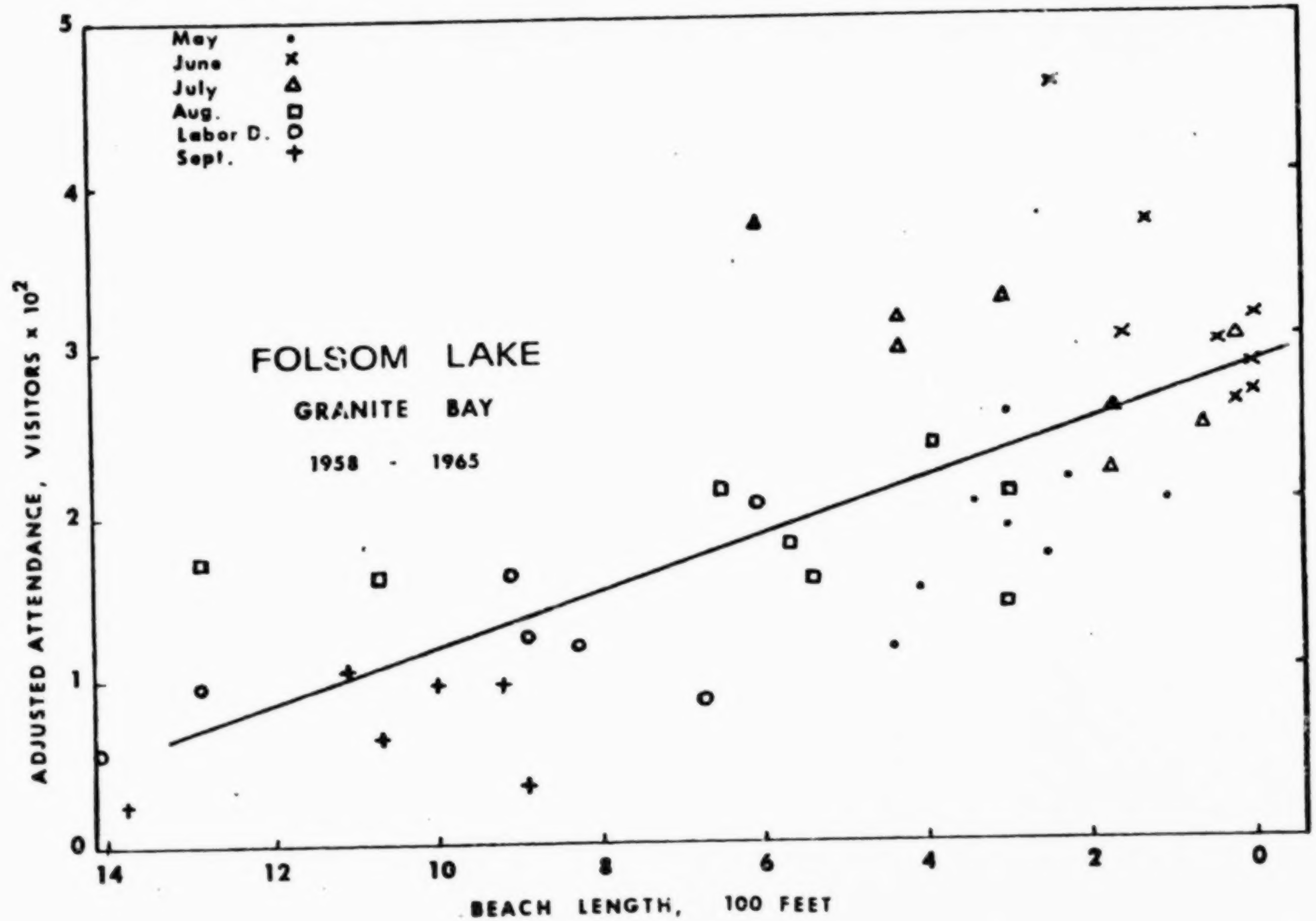

FIGURE 3. RELATIONSHIP BETWEEN ADJUSTED ATTENDANCE AND BEACH LENGTH

TABLE II

CORRELATION COEFFICIENTS

GRANITE BAY, FOLSOM LAKE, 1958-1965

	Attendance vs. :		
Month	Surface Elevation	Maximum Temperature	Maximum Wind
May	.5050	.7250	-.5407
June	-.8447	.7574	.1718
July	-.6393	-.4459	.6193
August	.5539	.1395	-.2298
Labor Day	.3805	-.5582	-.7870
September	.3322	-.3651	-.7343
Entire Season	.7155	.3009	-.0823

TABLE III

F TEST VALUES

GRANITE BAY, FOLSOM LAKE, 1958-1965

	Adjusted Attendance vs. :		
Month	Surface Elevation	Maximum Temperature	Maximum Wind
May	2.05	6.65	1.65
June	14.95	8.08	0.12
July	4.15	1.49	2.49
August	2.66	0.12	0.22
Labor Day	1.02	2.72	6.51
September	0.74	0.92	4.68

For the 5% level of significance, the F value is 5.99 with 1 and 6 degrees of freedom.

For the 1% level of significance, the F value is 13.75 with 1 and 6 degrees of freedom.

Entire Season	48.26	4.58	0.23

For the 5% level of significance, the F value is 4.06 with 1 and 46 degrees of freedom.

For the 1% level of significance, the F value is 7.24 with 1 and 46 degrees of freedom.

In general, temperatures in the seventies coincided with low attendance figures and higher attendance figures were recorded when the temperatures were in the eighties. A significant relationship apparently exists between temperature and attendance early in the recreational season. Significant relationships also occurred at Beals Point, an area frequented by families with small children, in May and at Granite Bay in May and June, a swimming and boating area attractive to adults and teenagers.

Multiple regression analysis did not yield any results not revealed by simple regression analysis, consequently the results are not reported.

Examination of the statistical analyses of attendance and reservoir operation (expressed as length of beach) yields some interesting results. The high, negative correlation coefficient in June could indicate that perhaps there is an optimum length of beach. Examination of Figure 3 shows that for the third week end in June (X), attendance increased if the beach length increased from zero, i.e., if the surface elevation was below the maximum pool elevation.

A significant relationship existed between attendance and reservoir operation (Figure 4) during the entire recreational season for the entire period of record. This result would lead one to accept the hypothesis that reservoir operation does influence attendance at Folsom Reservoir. Inspection of the results for a particular time period (such as the third week end in August) during the recreational season reveals that the attendance was not influenced by reservoir operation.

Why are the results contradictory? Evidently people who attend Folsom Reservoir are cognizant of the general seasonal trend in the operation of the reservoir. Whether the level is especially high or low during a particular month is evidently not too important to the visitors, but the relevant factor is the relationship of the level to last month or next month.

Why does attendance continually drop during the summer, similar to the drop in surface level or when the length of beach increases? Folsom Reservoir loses its attractiveness to swimmers during the summer because of the increasing distances from shade and facilities to the water. At low surface levels, the bathing area becomes muddy and wasps and insects become pests.

Another factor that contributes to the reduction in attendance at Folsom Reservoir is the availability of alternative opportunities. During the late summer the lakes and reservoirs in the high Sierras become more attractive due to better climatic conditions and the State Fair during the Labor Day week end also attracts many persons.

This study started to be a quantitative investigation of the influence of reservoir operation on reservoir recreational attendance.

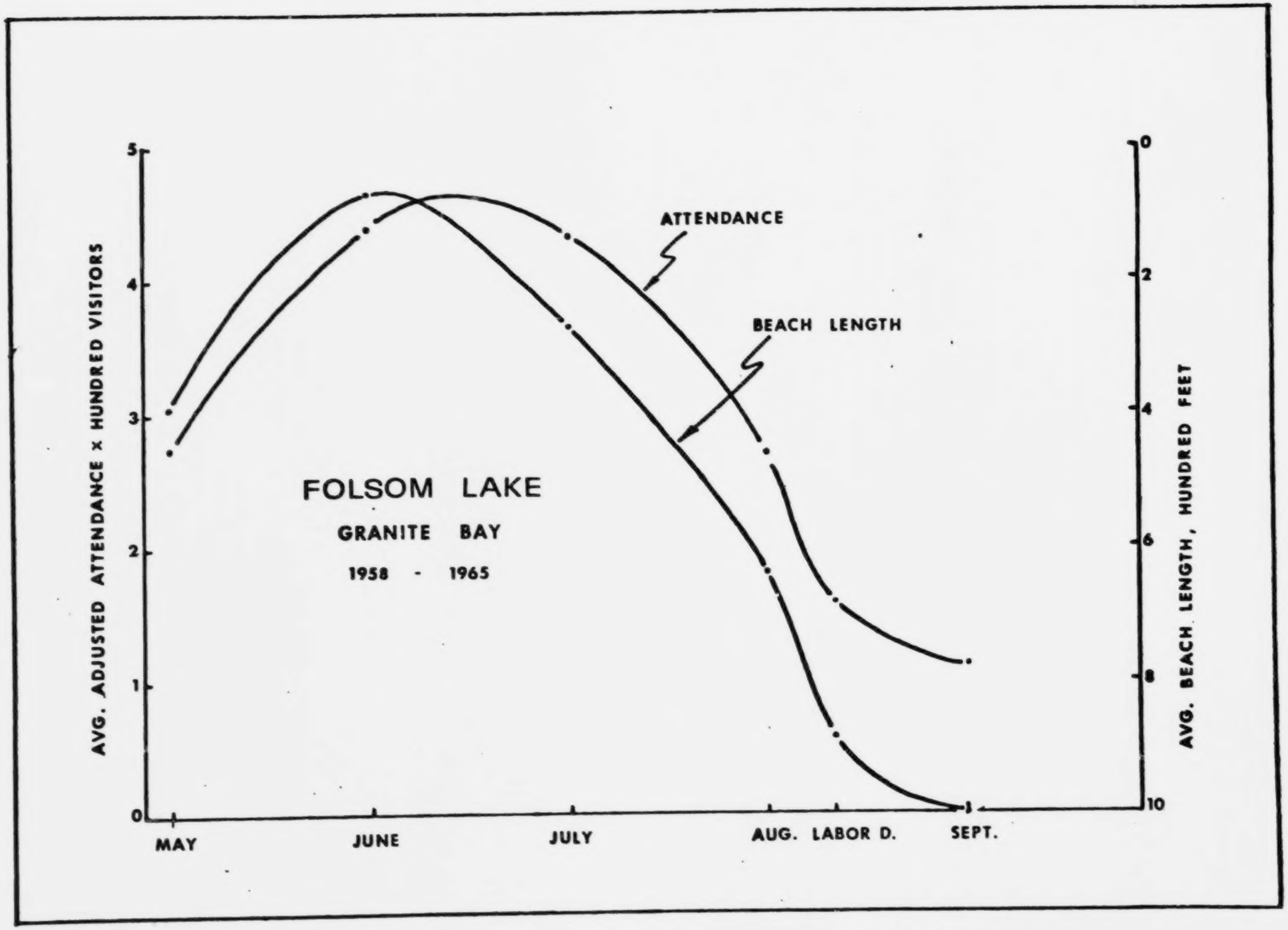

FIGURE 4. RELATIONSHIP BETWEEN AVERAGE ADJUSTED ATTENDANCE AND AVERAGE BEACH LENGTH

Attendance at Folsom Reservoir apparently drops during the summer because of a reduction in the quality of the recreational experience.

Evidently the average operating curve (Figure 4) is an approximation of the quality of the recreational experience. When the water level increases, the quality of the recreational experience increases and more visitors are attracted to the site. When the water level decreases, marginal users cease to use the area and probably visit alternative sites.

Use of Results

How can the results of this investigation be applied to the development of benefit functions for recreation associated with a reservoir? The writer proposes that for reservoirs similar to Folsom, the average operation curve (length of beach) could be used to reflect the quality of the recreational experience and the expected distribution of attendance during the recreation season.

During periods of extreme drought, the benefits from recreation would be reduced, If a decision had to be made between maintaining a pool level for recreation or releasing water for downstream uses, an indication of the anticipated change in attendance would be available. However, it must be remembered that during periods of normal pool levels, the attendance is not significantly influenced by reservoir fluctuations.

The proposed approach would be most applicable for planning purposes. Different operations studies could be simulated and different operating curves would produce different attendance estimates and thus, different recreation benefits. Sensitivity analysis could help settle conflicts between recreational uses of stored water and releases for downstream beneficial uses.

Conclusions

At Folsom Reservoir, seasonal attendance is influenced by the general quality of the recreational experience. The average operating curve or length of beach can be used to develop the expected seasonal fluctuations in attendance. Evidently attendance during a particular time period during the recreational season is not significantly influenced by reservoir operation, but attendance is influenced by the overall, seasonal pattern of fluctuations.

Extrapolation of these results to other reservoirs must be conducted with due caution. For reservoirs offering similar recreational experience and operational characteristics, the results should prove helpful to recreation planners and reservoir operators.

ACKNOWLEDGMENTS

Appreciation is extended to the many people who provided the data analyzed herein and suggested helpful references.

Mr. John Apostolos helped with the analysis of the data and performed the computer operations.

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APPENDIX IV

INPUT DATA

Summary

- I. Hydrology
  - A. Upstream Hydrology
  - B. Downstream Hydrology
  - C. Willamette River Hydrology
  - D. Evaporation
  - E. Flows Required in Calapooia River for Fishery Benefits
  - F. Irrigation Demands (Full Development)
  - G. Recreation Demands (Ultimate Development)
    - 1. Recreation ATtendance
    - 2. Influence of Reservoir Operation on Recreation Attendance
  - H. Expected Summer Inflow to Reservoir
- II. Economic Model
  - A. Drainage Benefits
    - 1. Drainage Benefits
    - 2. Drainage Benefit Function
    - 3. Drainage Costs
  - B. Flood Control Benefits
    - 1. Estimation of Peak Instantaneous Flows
    - 2. Conversion of Flows to Flood Stages
    - 3. Flood Damages (Calapooia Basin)
    - 4. Flood Damages (Willamette River)
  - C. Irrigation Benefits
    - 1. Target Benefit
    - 2. Irrigation Benefit Function
    - 3. Irrigation Costs

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D. Fishlife Enhancement Benefits
    1. Summary of Annual Benefits
    2. Enhancement Costs
    3. Fishery Benefit Functions
E. Water Quality Benefits
    1. Procedure
    2. Incremental Water Quality Benefits
    3. Water Quality Benefit Function
    4. Incremental Annual Associated Costs
    5. Water Quality Values for the Analytical Model
F. Recreation Benefits
    1. Visitation Value
    2. Recreation Benefit Function
    3. Cost Estimate
G. Reservoir Costs
    1. Initial Reservoir Costs
    2. Operation, Maintenance, and Repair

INPUT DATA
TO BASIN MODEL

HYDROLOGIC AND ECONOMIC

The purpose of this Appendix is to identify the original sources of input data used in the Calapooia River Basin Simulation Model and to indicate the method and extent of modification and extrapolation.

I. Hydrology

A. Upstream Hydrology

(Flow at Holley, Oregon, proposed reservoir site.)
Daily flows were obtained from

1. U.S. Geological Survey Water-Supply Papers, Surface Water Supply of the United States, Part 14. Pacific Slope Basins in Oregon and Lower Columbia River Basin, U.S. Government Printing Office, Washington, D. C. 1936 through 1960.

2. U.S. Geological Survey Surface Water Records of Oregon, U.S. Geological Survey, Portland, Oregon. 1961 through 1964.

Flows were rearranged and analyzed according to procedures outlined in Appendix II, Daily Streamflow Dimulation.

B. Downstream Hydrology

(Flow three miles above confluence of Calapooia with Willamette River near Albany, Oregon.)
Daily flows were obtained from the same sources as the upstream hydrology and were rearranged in a similar manner.

C. Willamette River Hydrology

(Generation of low flows at Salem, Oregon. U.S. Army Corps of Engineers, "Willamette River Reservoir Regulation Study." Portland, Oregon, 1959 (Unpublished).

In this study the Corps routed 30 years of monthly historical flows (1926-1955) through the authorized 14 reservoir Willamette Basin System. During six of the 30 years the target flow of 6000 cfs at Salem, Oregon was not achieved. These routed, insufficient historical flows were drawn by distribution free methods to simulate low flow conditions. Values were adjusted when necessary to vary linearly on a daily basis and still maintain the monthly average.

SUMMARY OF ROUTED HISTORICAL MONTHLY LOW FLOW YEARS

Willamette River at Salem - W.R.

Release from proposed Holley Reservoir - H.

Flow at Salem without release - F.S.

(used to simulate Willamette River low flows)

	Year	June	July	August	September
	1926				
W.R.		4600	4600	4600	5731
H.		100	50	50	65
F.S.		4500	4550	4550	5666
	1930				
W.R.		7278	6000	5895	6624
H.		100	187	211	51
F.S.		7178	5813	5684	6573
	1934				
W.R.		5500	4600	4726	6683
H.		100	50	50	50
F.S.		5400	4550	4676	6633
	1940				
W.R.		5640	4840	4873	6175
H.		100	198	193	140
F.S.		5540	4642	4680	6035
	1941				
W.R.		7161	4580	4647	7661
H.		100	50	50	191
F.S.		7061	4530	4597	7470
	1944				
W.R.		7173	5400	5400	6758
H.		100	50	396	54
F.S.		7073	5350	5004	6704

Water quality demands are composed of flows or volumes of water necessary to increase simulated flows to target minimum flows in the Willamette River.

D. Evaporation

Month	ER, SFM/AC[a]	Temp, °F[b]
April	0.00300	50.8
May	0.00495	56.1
June	0.00595	60.9
July	0.00830	66.6
August	0.00690	65.9
September	0.00460	61.5
October	0.00190	53.2

a. U.S. Army Corps of Engineers, "Report on Redistribution of Irrigation and Other Water Resource Benefits" Portland, Oregon, Rev. No. 1960. Chart 4.

Evaporation from Reservoirs in the Willamette Valley was converted to ac-ft per day per acre of reservoir surface area. The monthly averages given in the table were adjusted to vary linearly on a daily basis and still preserve the monthly average.

b. U.S. Department of Commerce, Climatological Data, National Summary. Mean monthly temperatures at Eugene, Oregon, were available but not incorporated in this model.

Evaporation in the simulation model was treated as a function of surface area and time of year. Considered in the evaporation rates were expected water temperatures, wind velocities, humidity, and cloud cover.

1. Available Data

Pool Elevation, ft. m.s.l.	Storage,[a] ac-ft	Surface Area,[b] Ac
694	186,000	---
685	160,000	2,850
660	97,000	---
643	---	1.720
590	---	500

a. Wilcox, B. E., Personal communication NPPEN-PL-9, dated 8 July 1966.

b. U.S. Army Corps of Engineers,"Preliminary Recreation Reconnaisance, Calapooia River, Holley Dam Site, undated, Received 24 July 1965.

2. Interpolated Input Data

Pool Elevation ft. m.s.l.	Storage, ac-ft	Surface Area Ac
699	200,000	2,975
692	180,000	2,910
685	160,000	2,850
677	140,000	2,690
669	120,000	2,431
661	100,000	2,221
651	80,000	1,914
638	60,000	1,559
620	40,000	1,159
602	20,000	763
560	0	0

E. Flows Required in Calapooia River for Fishery Benefits[a]

Date	Minimum Desirable Flows, cfs	
	Holley Dam to Brownsville Diversion	Brownsville Diversion to Willamette River
Sept. 1 to May 31	130[b]	130[b]
June 1 to June 15	250[c]	130[d]
June 16 to Aug. 31	250[c]	90[e]

Maximum Temperature of Water Released from Reservoir
October 1 - 55°F
Summer - 60°F

a. All data obtained from Mr. Kenneth Johnson, U.S. Army Corps of Engineers during meeting on July 28, 1966, in Portland, Oregon.

b. Little or no irrigation releases for fish spawning.

c. High flows for fishery and irrigation.

d. Minimum flow for fishery.

e. Lower minimum flow for fishery in lower reach because fish have moved upstream.

Simulation model used minimum flows in lower reach as fishery target flow because irrigation releases provided sufficient flows to exceed minimum flow target for fishery in upper reach.

F. Irrigation Demands (Full Development)

Downstream irrigation demands were obtained from Halter and Miller's work.[a] Original data were provided by the Corps of Engineers from estimates by the Bureau of Reclamation.

Month	Downstream Irrigation Demand, Ac-ft
April	2,100
May	5,400
June	14,000
July	24,800
August	21,300
September	2,300
Total Demand	69,900 Ac-ft

Demands were incorporated in the simulation model on a daily basis. The daily demand varied linearly within 15 day periods on the basis of a percentage of the target output.

a. Halter, A. N. and S. F. Miller, "River Basin Planning: A Simulation Approach," Special Report 224, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon, November, 1966, 117p.

G. Recreation Demands (Ultimate Demand)

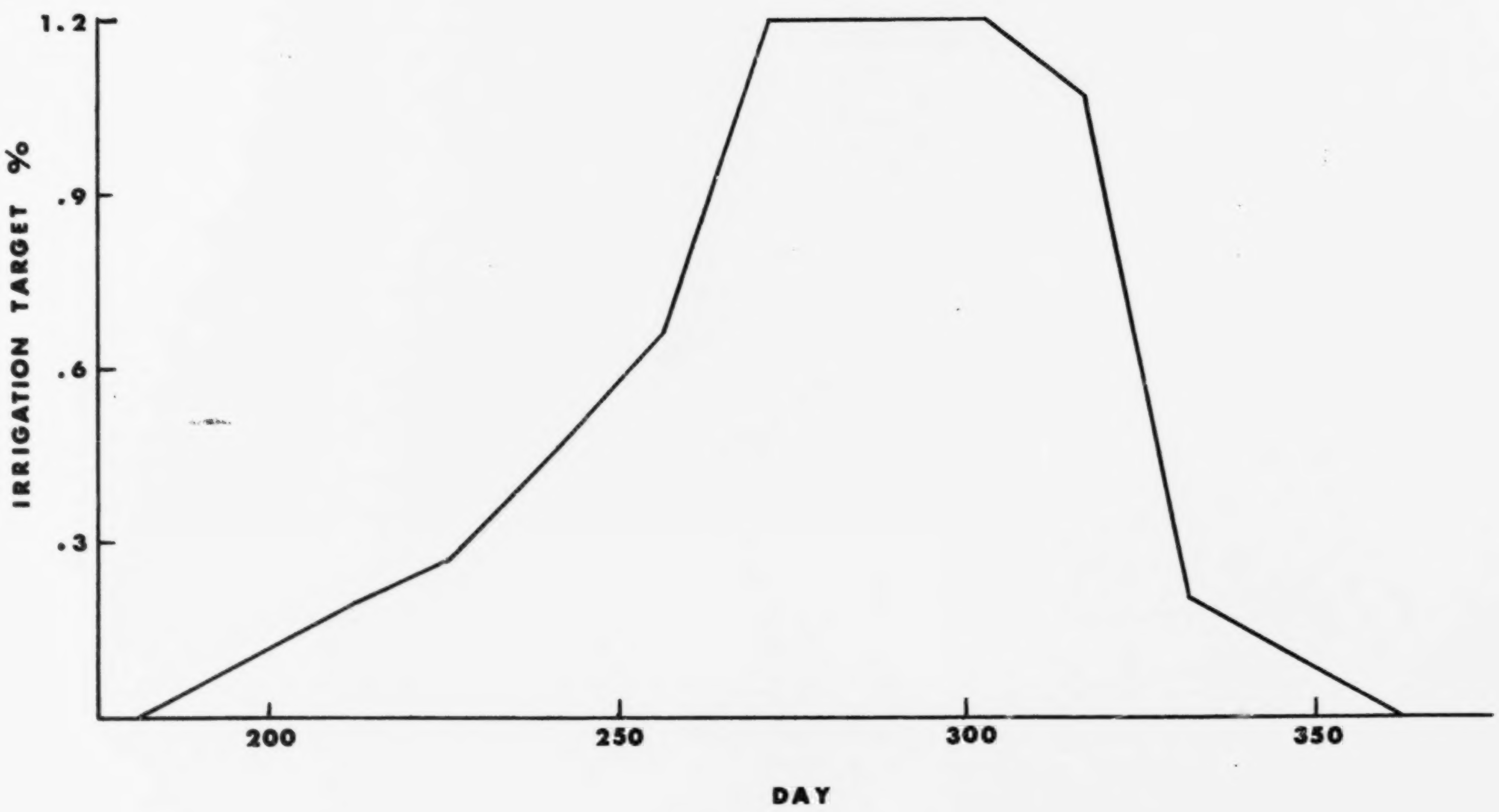
1. Recreation Attendance
   Recreation Potential for 685-foot Pool Elevation[a]
   (Storage, 160,000 ac-ft; Surface Area, 2,850 acres)

Time	Estimated Usage, Without Project or Parks	Visitor-Days, With Project
Present	5,000	NA
3 years after construction	-	100,000
100 years after construction	10,000	500,000[b]

a. Wilcox, B. E., Personnel communication NPPEN-PL-9, dated 8 July 1966.

b. Expected attendance used in simulation model.

2. Influence of Reservoir Operation on Recreation Attendance
   A definite reduction in visitor-days was shown in a study reported in Appendix III. A statistical analysis of attendance data and width of beach (distance from high water line to water surface showed) that attendance drops as the distance to water increases at the Granite Bay State Recreation Area on Folsom Lake, near



IRRIGATION DEMAND

metropolitan Sacramento. These relationships were extended to a potential recreation site at Holley in this simulation model. The recreation season for both areas was assumed to be from the day before Memorial Day (May 30) through September 15.

Comparison of Holley Reservoir and Folsom Reservoir Recreation, potential and existing

Item	Holley[a]	Folsom[b]
Slopes in recreation area	3 to 20%. Used 10% on basis of U.S.G.S. topo map contours in potential area.	3% at Granite Bay
Change in pool elevation during recreation season	Max. 685 Min. 645 Elev. 40 ft	Max. 470 Min. 390 Elev. 80 ft
Anticipated Usage	500,000 persons within 1 hour's driving time now. Estimate threefold increase in next 50 years.	During Folsom Study. Sacramento County Population 1955 - 374,300 1965 - 617,200

To approximate the Corps annual attendance estimate of 500,000 man-days (ultimate demand) 100 years after construction of the dam,[a] this simulation model assumed a daily attendance of 5000 visitors (actually the daily average for a week) when the reservoir if full. Attendance drops linearly to zero as the width of beach increases to 1500 feet. The beach will never reach this width; therefore, even if the reservoir is empty, there will be some visitors.

a. U.S. Army Corps of Engineers, "Preliminary Recreation Reconnaisance, Calapooia River, Holley Dam Site, Undated. Received 24 July 1965.

b. Apostolos, John A., "Factors Influencing Recreation on Reservoir," paper submitted to 1967 ASCE Student Content, Reno, Nevada.

II. Expected Summer Inflow to Reservoir

To allocate available water during the flow periods the expected flow during this time span should be considered. A prediction equation was developed using regression analysis to estimate summer inflow on the basis of spring flows.

Expected Summer Inflow, sfd = 8260 + (0.029)(Sum of three previous months, sfd)

The regression coefficient (0.029) indicates that the flow during the three months before the low flow season does not exert a large influence on the low flows and/or the spring flows are much larger than the summer flows. To avoid over estimating expected flows which could cause severe losses in benefits if the expected flows were not available, safety factors from 0.8 to 1.0 were applied to the expected flows with virtually no change in the average annual net benefit. The value of 0.9 was the optimum safety factor.

II. Economic Model

A. Drainage Benefits

1. Drainage Benefits
Maximum Annual Drainage Benefits, Calapooia River, 1964 Dollars[a]

Channel Capacity, cfs	Maximum Annual Benefits[b] Dollars
5,000[c]	0
11,000	200,000
21,000	500,000

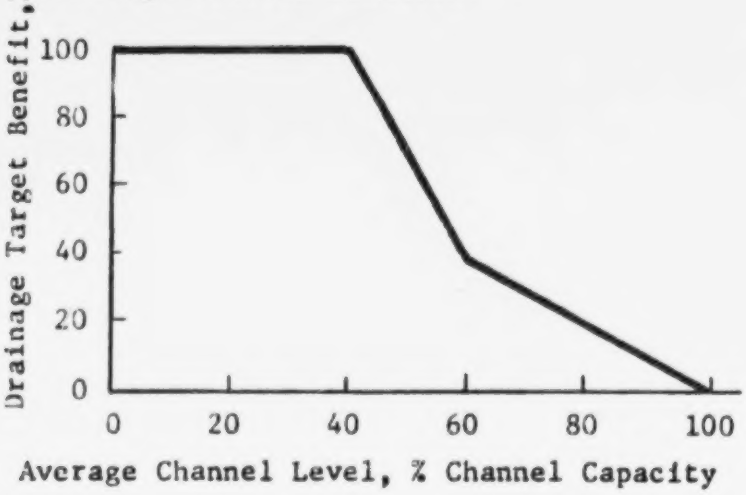
a. Halter, A. N. and S. F. Miller, "River Basin Planning: A Simulation Approach," Special Report 224, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon, November, 1966. 117p.

b. Estimated by Corps of Engineers

c. Natural channel size.

Benefits from channel sizes other than values listed above were assumed to vary linearly in the simulation model. Values were not extrapolated beyond a channel capacity of 21,000 cfs nor an annual benefit of $500,000.

2. Drainage Benefit Function[a]



a. Halter, A. N. and S. F. Miller, "River Basin Planning: A Simulation Approach, "Special Report 224, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon, November, 1966, 117 p.

Crop production can be increased if drainage is provided soils with poor drainability. Full drainage benefits can be achieved if the average channel level during the drainage season (March, April, May, and June) is below 30 percent of the channel capacity. When the average channel level exceeds 30 percent of the channel capacity the drainage benefit function is reduced as shown above.

3. Drainage Costs
Costs of Improving or Increasing Channel Capacity[a]

Calapooia River, 1964 dollars

Channel Capacity, cfs	Total Construction Cost,[b] Dollars x 10^6
5,000[c]	0.1
11,000	1.6
21,000	8.0

Operation, maintenance and repair are estimated at 10 percent of the authorized costs (life of 100 years assumed)[a]

a. Halter, A. N. and S. F. Miller, "River Basin Planning: A Simulation Approach," Special Report 224, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon, November, 1966. 117p.

b. Estimated by Corps of Engineers

c. Natural channel capacity. Some channel improvement will be necessary to accommodate reservoir releases.

Costs listed above are solely for channel improvement and increase in channel capacity. These improvements and increases in channel capacity also will reduce flood losses. The costs of actually draining the land are not included. The greater the channel capacity and the lower the average channel level, the more effective will be the drainage outlets.

B. Flood Control Benefits

1. Estimation of peak instantaneous flows.
Flood damages were estimated on the basis of peak instantaneous flows. Peak flows were calculated from simulated average daily flows. Regression analysis of historical data[a] yielded the following relationships.

Downstream Station, Albany
Inst. Peak, cfs = -846 + 1.209 (Ave. Daily Flow, cfs)
Correlation Coef., r = 0.954 and n = 24.

Upstream Station, Holley
Inst. Peak, cfs = 515 + 1.162 (Ave. Daily Flow, cfs)
Correlation Coef., r = 0.967 and n = 24.

a. U.S. Geological Survey Water Supply Papers and Surface Water Records of Oregon (See ref. 1 & 2, Section 1A of this Appendix.)

In the simulation program, a table was prepared from the regression equations and the peak flows were obtained from the table on the basis of the simulated average daily flow.

2. Conversion of Flows to Flood Stages
Relationship between Channel Flow and Flood Stage at Shedd[a]

Channel Flow, cfs	Flood Stage at Shedd, ft Channel Capacity, cfs		
	5,000	11,000	21,000
0	10.0	10.0	10.0
10,000	15.75	14.0	11.0
20,000	16.6	15.75	14.0
30,000	16.9	16.35	15.1
40,000	17.15	16.6	15.75
50,000	17.3	16.75	16.15
60,000	17.5	16.9	16.35
70,000	17.65	17.05	16.5
80,000	17.82	17.15	16.6
90,000	18.0	17.25	16.7

a. Halter, A. N. and S. F. Miller, "River Basin Planning: A Simulation Approach," Special Report 224, Agricultural Experiment Station, Oregon State University, Corvallis, Oregon, November, 1966, 117p.

Flood stage at Shedd is used because flood stages at the downstream simulation station are influenced by backwater resulting from flows in the Willamette River

3. Flood Damages (Calspooia Basin)
Flood Damages Based on Flood Stage at Shedd

Flood Stage at Shedd, ft	Flow at Shedd, Existing Channel cfs	Damage, Halter-Miller[a] Dollars	Damage Wilcox[b] Dollars	Damage This Project Dollars
10	0	0		0
11	1,000			0
12	1,800	2,200		2,200
13	3,000			5,500
14	4,500	16,000		16,000
15	6,700		40,000	40,000
16	12,000	135,000	200,000	200,000
17	34,000		1,400,000	1,400,000
18	90,000	550,000		4,400,000
20		1,000,000		

a. Halter-Miller, Corps of Engineers estimates based on 1964 stage of development

b. Wilcox, B. E., Personal communication NPPEN-PL-9 dated 13 December 1966.

Data in Wilcox column taken from "Discharge-Damage Curve, Willamette River Basin, Calapooia River, Zone B, Discharge at Shedd, April 1, 1966. 1965 Prices and Development" The curve contained the 1964 flood which had a discharge of 22,500 cfs and caused $780,000 in damages (values taken from plot on curve).

The flood stage at Shedd is used to indicate flood damages resulting from Calapooia River flows because the flood stage at Albany is often influenced by backwater from the Willamette River.

4. Flood Damages (Willamette River below confluence with Calapooia River)
"Benefits creditable to Holley Reservoir for flood damage reduction along the Willamette River are based on all 14 authorized Willamette Basin reservoirs being operated as a system. Distribution of benefits to various reservoirs is in proportion to each reservoir's contribution to reduction of average annual flood damages. At 1965 prices and development, these benefits would amount to approximately $610,000 annually for 90,000 acre-feet of flood control storage at Holley Reservoir," Wilcox, B. E., Personal communication NPPEN-PL-9 dated 13 December 1966.

To incorporate average annual flood benefits for damage reduction along the Willamette River was a problem, since only 1 of 14 reservoirs was being studied. Reductions in flood damages should be recorded in the simulation model when they occur, rather than on an annual basis. The necessity of providing storage of 90,000 ac-ft for flood control was questioned. A review of historical records indicated that most severe floods on the Calapooia River had a duration of three days (3 days of high flows). One hundred years of reservoir inflows were simulated and yielded the following results:

Rank	Largest Mean 3-Day Flow, cfs	Volume, Ac-ft
1	14,139	84,834
2	11,562	69,372
3	10,897	65,382
4	10,758	64,548
5	10,457	62,742

These results indicated that if no flows were released from the reservoir during a severe flood, a flood storage capacity of 60,000 ac-ft could hold most floods. Even under the worst condition, the average release would be approximately 4100 cfs, (neglecting any surcharge storage) which would be small in comparison with the total flow in the Willamette River. Consequently flood benefits from a reduction in flows in the Willamette River were reduced proportionally, based on the unavailability of storage available to contain a three-day runoff of 60,000 acre feet. When Holley reservoir is operated as an integral part of the Willamette Basin reservoir system, it may be required to hold a major portion of flood flows longer than three days.

To allow for a flood benefit from reduced flows in the Willamette River, an annual flood benefit of $160,000 was arbitrarily selected simply to be conservative. Since this is a fixed, annual value, the size of the reservoir and other target outputs would not change if another value was inserted, only the maximum net benefits and benefit/cost ratio would change.

$$\text{Will. River Flood Benefit} = \$160{,}000/\text{yr}\left(\frac{\text{Target Flood Storage 60,000 Ac-ft}}{\text{60,000 ac-ft + Insuf. Capacity}}\right)$$

$$\underset{\text{(zero or positive)}}{\text{Insufficient Capacity, Ac-ft}} = \text{3 day Inflow} - \underset{\text{Storage}}{\text{Available Flood}}$$

C. Irrigation Benefits

1. Target Benefits

Irrigation Capability, acre[a]	53,400
Annual Net Benefits, $/acre[b]	$10.35
Total Annual Net Benefits	$552,690

Benefits of $552,690 would result if the irrigation target output of 69,900 ac-ft was met.

a. Provided Corps of Engineers by Bureau of Reclamation

b. Halter-Miller Report

In the simulation model, the target benefit was adjusted proportionally on the basis of the target output for irrigation water in ac-ft.

2. Irrigation Benefit Function
If sufficient water is not available to meet irrigation demands, losses in net benefits result. The magnitudy of the dollar loss is a function of the severity, duration, and time of the shortage. The selection of a loss function for the simulation model was a compromise between loss functions published in two different references as shown in the following figure (Halter-Miller report and Bower, Blair T. in "Design of Water Resource Systems," by Maass A., et al, Harvard University Press, Cambridge, 1962, pp. 263-298).

3. Irrigation Costs

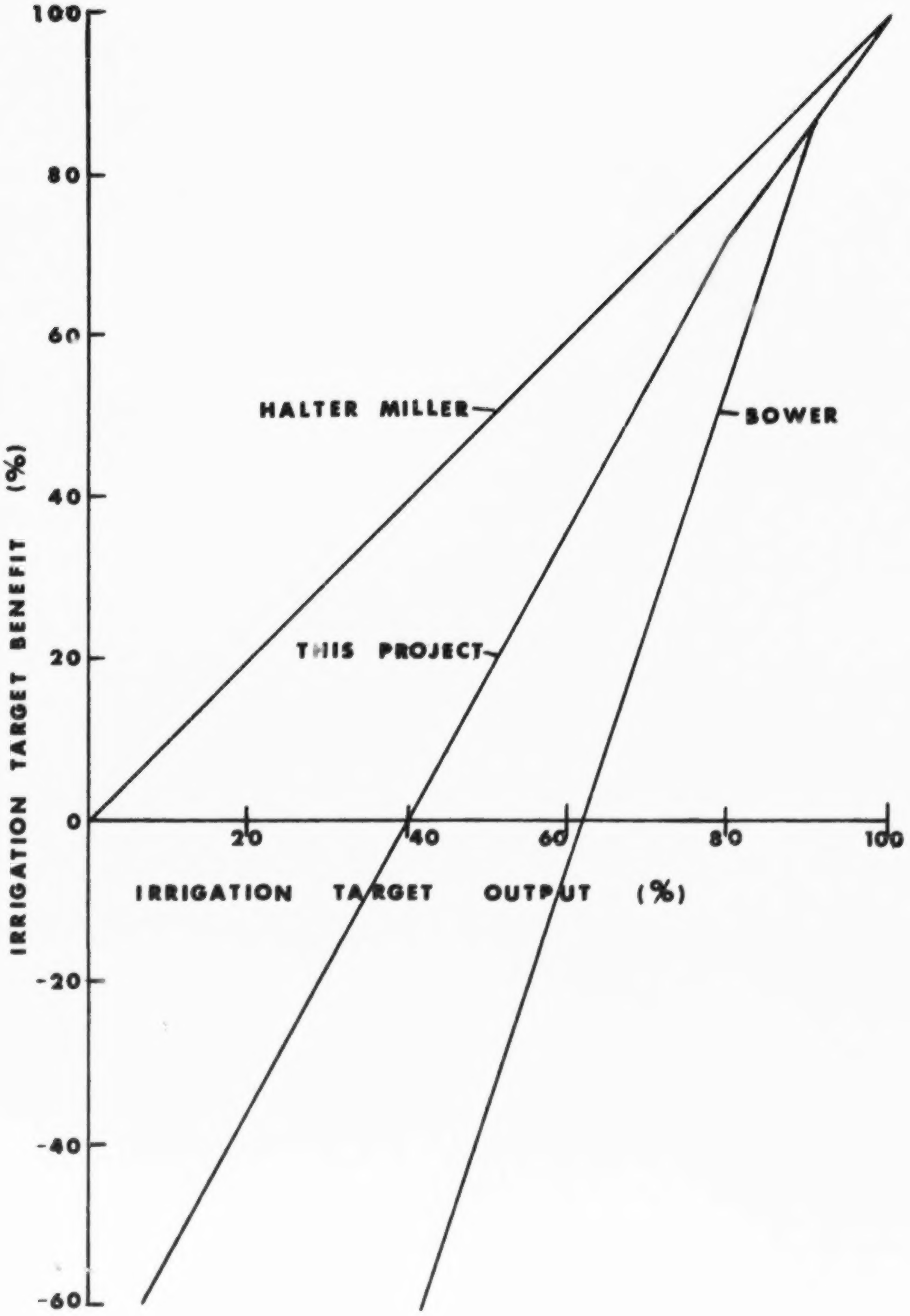
Irrigation Capability, acre[a]	53,400
Construction Costs, $/acre[a]	$ 17.44
Total Construction Cost	$931,296

Operation, maintenance, and repair are estimated at 7.5 percent of amortized costs.[b]

a. Provided Corps of Engineers by Bureau of Reclamation.

b. Halter-Miller Report

Costs above original irrigation target output of 69,900 ac-ft were assumed to increase by the square of the ratio of the new irrigation target to the original irrigation target. If the irrigation target output was reduced, the costs were reduced proportionally to the output.



IRRIGATION BENEFIT FUNCTION

D. Fishlife Enhancement Benefits

At the time this project's economic model was prepared, the data below were obtained from Mr. Kenneth Johnson, U.S. Army Corps of Engineers, on July 28, 1966.

	Average Annual Projected Fishery Benefits, Dollars				
PLAN	A	B	B	D	F
Reservoir Capacity, Ac-ft	186,000	201,000	186,000	160,000	97,000
Minimum Conservation Pool, Ac-ft (For Temperature Control)	51,000	51,000	36,000	39,000	7,000
Anadeomous Fish	$334,000	$334,000	$334,000	$264,000	None
Reservoir Sport Fish (Angler Use)	$154,000	$160,000	$154,000	$145,000	$105,500
Downstream Sport Fish (Angler Use)	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 30,000
Total Fishery Benefit	$578,000	$584,000	$578,000	$499,200	$135,500

The identical benefits for plans A and C and different minimum conservation pools represent the opinions of different agencies at this time regarding the minimum conservation pool necessary to satisfy the temperature control target of 60°F or lower during the summer and 55°F or lower after October 1. Plan A was selected as the basis for preparing the economic model for this project. On December 7, 1967, Mr. Johnson indicated that the minimum conservation pool would probably be 51,000 ac-ft. Fishlife enhancement benefits were still being reviewed at the time this report was prepared (Dec. 1969).

1. Summary of Annual Fishery Benefits

   a. Reservoir Sport Fish (Angler use) = $154,000

   b. Anadromous Fish = 334,000
   Downstream Sport Fish (Angler use) = 90,000

   Total Benefits $424,000

   Release for minimum flow and storage for temperature control.

2. Enhancement Costs

   An egg collection station below Holley has been proposed by the Oregon State Game Commission

   Total Construction Costs $800,000[a]

   Operation Maintenance, and Repair are estimated at 10% of construction costs.[b]

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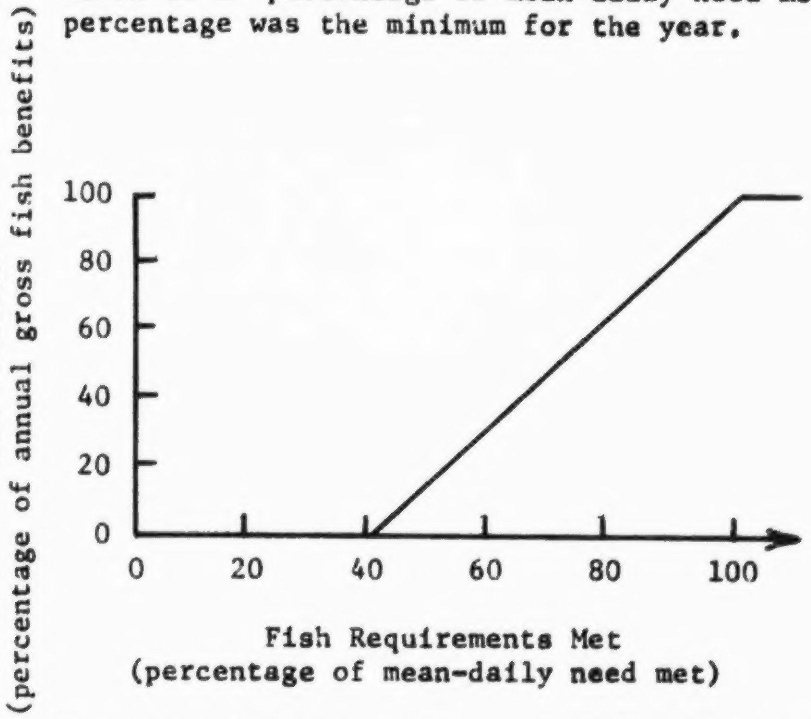
[a] Estimated by the Corps of Engineers

b. Halter-Miller report

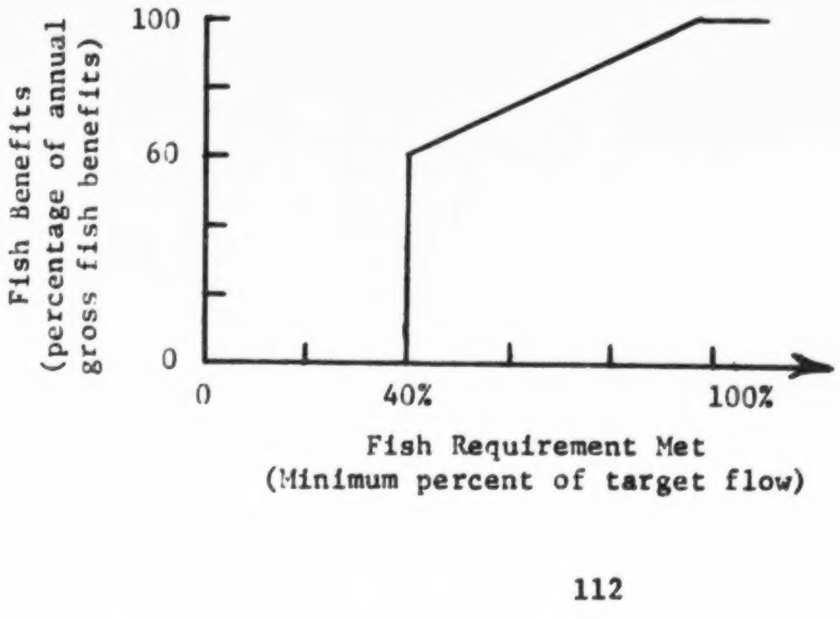
3. Fishery Benefit Functions

a. Other Fishery Benefit Functions

The exact response of fish to low flows is not well defined because of the influence of many other factors, such as water quality (temperature, dissolved oxygen). Halter and Miller used a benefit function based on minimum flows and related the flows to a "percentage of mean-daily need met," where the percentage was the minimum for the year.

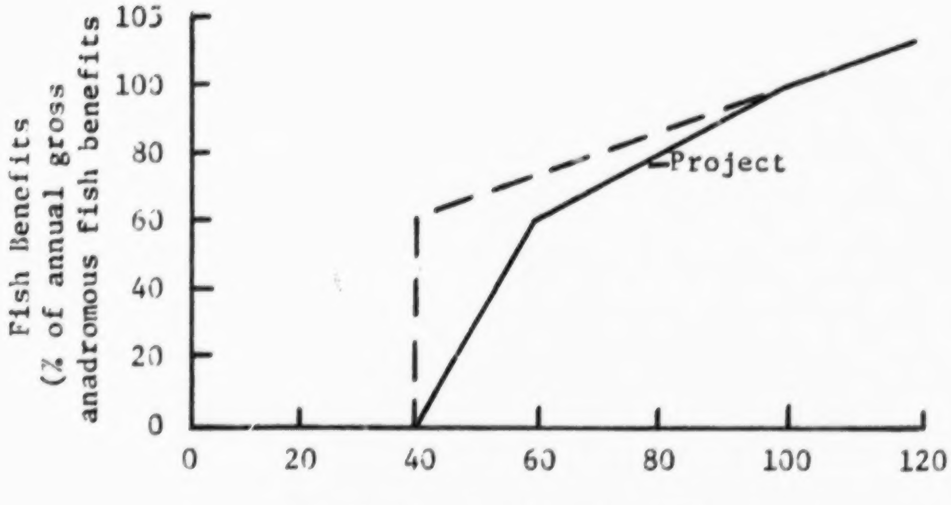


Mr. Kenneth Johnson, Corps of Engineers, indicated during a meeting on July 28, 1966 that temperature control was critical to the fish benefit function and that the benefit function shown below was being used.

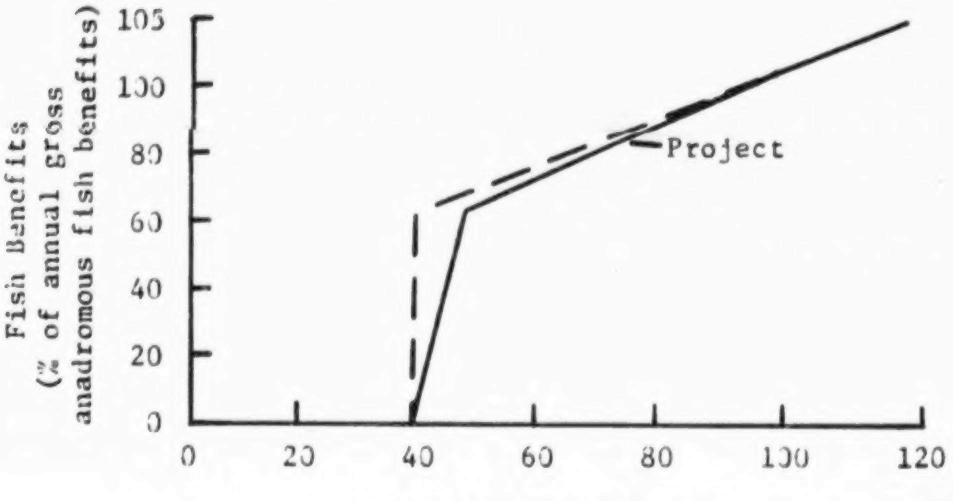


b. Project Fishery Benefit Functions

(1) Anadromous Fish Enhancement
To achieve full anadromous fish benefits, both minimum flows and temperature control must be achieved and maintained. Temperature control was based upon the ability of the reservoir to maintain a minimum conservation pool of 51,000 ac-ft. In an attempt to more accurately describe a benefit function similar to field conditions, this project assumed the benefit function shown below. The simulation model determined the minimum annual percent flow target and percent conservation pool target and used the minimum of the two values to estimate the anadromous fishery benefit.



% Minimum Conservation Pool
Anadromous Fishery Benefit Functions

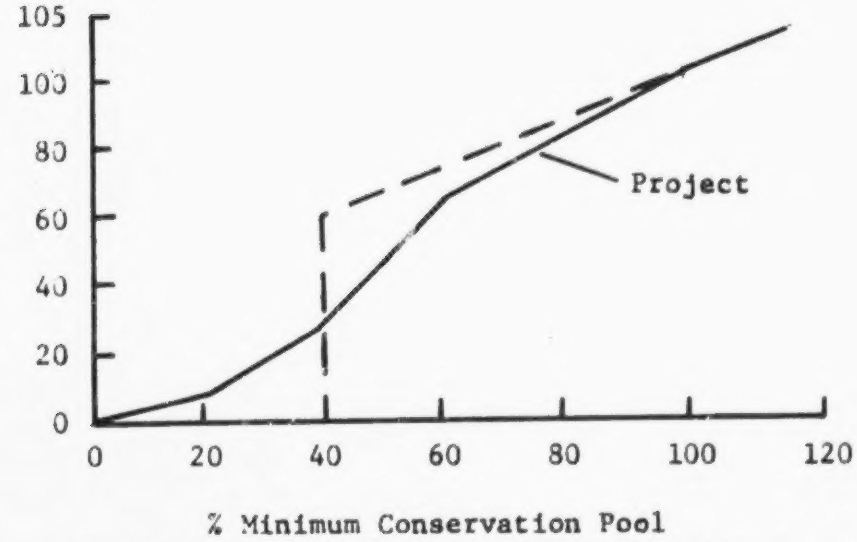


% Minimum Flow Target-
Anadromous Fishery Benefit Functions

The deviation of the project benefit function from the one provided by the Corps was justified on the belief that the percentage of the benefits does not drop from 50% to 0% at the 40% target level, but is more gradual as reflected in the project benefit function. If the target was exceeded, a slight increase in benefits was allowed based on the belief that fishery benefits do not cease to increase after the target is met.

(2) Reservoir Sport Fish Enhancement

A benefit function for reservoir sport fishery was not available. The simulation model used a benefit function similar to the anadromous fishery function with some pertinent modifications.



Reservoir Sport Fishery Benefit Functions

When the minimum conservation pool level drops below 40% of the target, a complete loss of the reservoir sport fishery does not seem realistic. Some fishermen would be expected to continue to attempt to catch fish.

E. Water Quality Benefits

1. Procedure

Previous work by Worley[a] and Kerri[b] has established the response of the Willamette River and its tributaries to various amounts of waste discharge. For different combinations of water quality objectives of DO of 4, 5, and 7 mg/l and coliform group bacteria MPN on 240, 1000, 2400, and 5000 per 100 ml Kerri used nonlinear programming to find the minimum cost of achieving the water quality objectives. Worley's computer program verified the ability of the receiving water to achieve the DO objective and Kerri's work verified the coliform objectives.

Costs of achieving the water objectives are tabulated in terms of initial treatment plant costs and annual maintenance and operation costs for minimum flow levels in the Willamette River of 4500, 5000, 5500, and 6000 cfs at Salem, Oregon.

Water quality benefits are measured in terms of reduced treatment costs resulting from flows at Salem above 4500 cfs, the minimum excepted flow (based on the routing of 30 years of historical flow) without the project under consideration. If a flow target above 4500 cfs can be established, then higher incremental degrees of waste treatment can be postponed by the release of water for water quality control. If the target is not met, then the annual benefit from avoided operation and maintenance costs is reduced proportionally, assuming that downstream water users must increase their operating costs or they incur some damages from the decreased water quality.

Any combination of water quality objectives will require a certain level of treatment by all waste dischargers in the basin. Therefore, for any selected water quality objective in the simulation model, the average annual net benefits should be reduced by an appropriate increment to account for the associated costs to the waste dischargers for their degree of treatment. The associated costs are a function of the degree of treatment required to meet water quality objectives at the minimum flow objective under consideration.

a. Worley, J. L., "A System Analysis Method for Water Quality Managing by Flow Augmentation in a Complex River Basin," U.S. Public Health Service, Region IX, Portland, Oregon (1963).

b. Kerri, Kenneth D., "An Investigation of Alternative Means of Achieving Water Quality Objective," Ph.D. Thesis, Oregon State University, 1965.

2. Incremental Water Quality Benefits for Q - 4500, 5000, and 6000 cfs are summarized in Table I.

3. Water Quality Benefit Function
Minimum flow in the Willamette River at Salem without this project's contribution is estimated as 4500 cfs on the basis of a Corps of Engineers' study which routed 30 years (1926-1955) of monthly flows through the Willamette Basin reservoir system. The minimum flow objective at Salem of the Corps is a flow of 6000 cfs. To determine the optimum target flow for water quality control, various targets were tested in the simulation model.

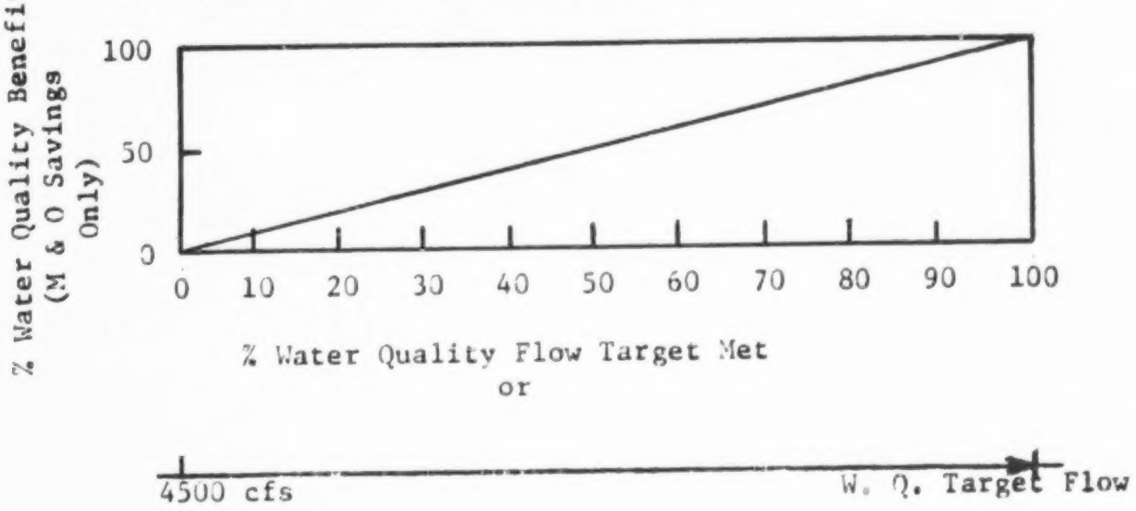
As previously described, the degree of treatment to meet different combinations of water quality objectives was determined for a flow of 4500 cfs at Salem. The benefits from flows released for water quality control are calculated on the basis of treatment not required if the target flow is met. The treatment was divided into facility costs and maintenance and operation costs.

TABLE I. WATER QUALITY BENEFIT SUMMARY

INITIAL PLANT COSTS, $\$ \times 10^6$
ANNUAL OPERATION AND MAINT. COSTS, $\$ \times 10^3$

Target Flow, cfs	DO mg/l	Total Coliform Group Bacteria MPN per 100 ml			
		5000	2400	1000	240
Q = 6000	4	0 0	.005 10.935	.096 18.279	8.798 1001.184
	5	.897 51.13	.897 61.89	1.067 68.025	10.147 1042.481
	7	8.813 473.904	23.333 487.774	23.525 496.862	30.481 1454.688
Q = 5000	4	.354 28.493	.325 33.951	1.596 45.789	10.234 1052.643
	5	1.072 69.564	1.572 91.892	3.727 82.580	11.353 1078.564
	7	12.273 855.508	27.503 863.226	28.305 819.168	33.182 1637.365
Q = 4500	4	.514 41.460	.495 44.539	6.246 269.461	12.410 1217.379
	5	3.790 87.880	4.988 135.862	8.623 205.559	39.389 1265.221
	7	16.488 1182,305	30.739 1104.023	35.580 1152.254	38.471 2041.408

The reduction in water quality benefits from a failure to meet the target water quality flow objective results from increased treatment costs by downstream water users. This reduction was assumed to be a linear function of the difference between the target flow for water quality and the minimum routed flow of 4500 cfs without the project as shown below.



Water Quality Target Flow Met
Water Quality Benefit Function

4. Incremental Annual Associated Costs
Q = 6000 cfs at Salem; i = 3 1/8%; n = 20 years
To maximize net benefits in the simulation model, the optimum low flow objective at Salem for all combinations of water quality objectives is 6000 cfs.

Annual Incremental Treatment Costs,[a]
in One Thousand Dollars

Dissolved Oxygen	Total Coliform Group Bacteria MPN per 100 ml			
mg/l	5000	2400	1000	240
4	--	56	88	1152
5	105	158	186	1245
7	826	877	888	1789

a. Kerri, Kenneth D., "An Investigation of Alternative Means of Achieving Water Quality Objectives," Ph.D. Thesis, Oregon State University, 1965.

5. Water Quality Values for Analytical Model
To estimate expected values of water released for flow augmentation, the low flow hydrographs were analyzed. For each hydrograph,

volumes of water necessary to increase flows to specified levels were calculated. Water quality benefits from higher flows were estimated and the value of the water in dollars per ac-ft was calculated for each increment.

Results from the analysis of the low flow hydrographs indicated that the V-shaped hydrographs consisted of three segments, whereas the one U-shaped hydrograph was composed of two segments similar to the second and third segments of the V-shaped hydrographs. The value of the first segment of water released for water quality control with the V-shaped hydrographs was approximately $12 per ac-ft. Values for the second and third increments were approximately $8 and $4 per ac-ft respectively.

F. Recreation Benefits

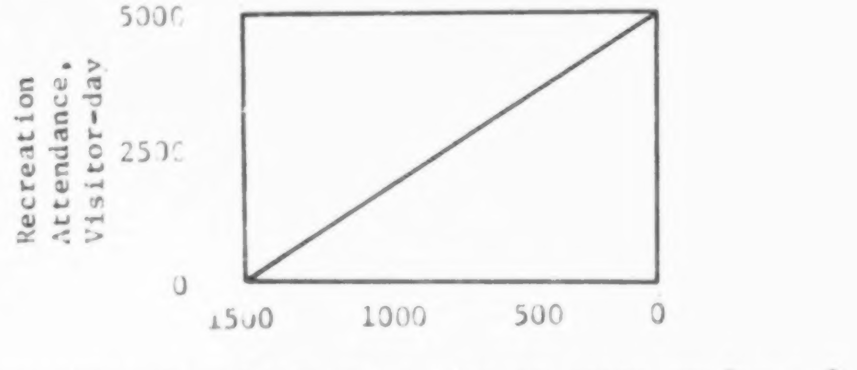
1. Visitation Value

"The Bureau of Outdoor Recreation has . . . concluded that reasonable visitation values for estimating a monetary benefit value would range between $0.75 and $1.00 per visitor-day. Full development of recreation potential would be contingent upon finding a non-Federal sponsor willing to share acquisition and development costs and operate and maintain recreation facilities as required by Public Law 89-72."[a] The simulation model used a recreation value of $1.00 per visitor-day.

a. Wilcox, B. E., Personal Communication NPPEN-PL-9 dated 8 July 1966.

2. Recreation Benefit Function

Recreation attendance decreases as the distance from the high-water line to the water surface increases. The value of a visitor day was assumed to be $1/visitor-day.[a]



Recreation Benefit Function

3. Cost Estimate
The estimated cost of initial and ultimate recreational development is $1,870,000 exclusive of land costs[a] as summarized in Table II.

G. Reservoir Costs

1. Initial Reservoir costs[a]

Total Storage	Maximum Pool	Estimated Cost*
186,000 Ac-ft	694 ft m.s.l.	$32,700,000
160,000 Ac-ft	685 ft m.s.l.	$27,900,000
97,000 Ac-ft	660 ft m.s.l.	$19,200,000

*Costs reflect all features of the project and include engineering, supervision and administration, and interest during construction. Downstream channel improvement costs totaling approximately $3,000,000 are included in each of the above estimates.

2. Operation, Maintenance, and Repair[b]
Operation, maintenance, and repair costs were estimated at 7.5 percent of amortized costs.

a. Wilcox, B. E., Personal communication NPPEN-PL-9 dated 8 July 1966.

b. Halter-Miller Study
The simulation model estimated initial reservoir costs using the above estimates, less $3,000,000. This data plotted close to a straight line and the cost of reservoirs of intermediate capacity were obtained by linear interpolation.

TABLE II. TOTAL COST OF RECREATIONAL DEVELOPMENT[b]

Initial development cost	$ 450,000
Future development cost	1,420,000
Total cost of development	$ 1,870,000
ANNUAL COST - INITIAL DEVELOPMENT	
M & O	$ 23,400
Replacement	8,700
Amortization	14,800
Total annual cost	$ 46,900
ANNUAL COST - FUTURE DEVELOPMENT	
M & O	$ 82,600
Replacement	34,100
Amortization	56,900
Total annual cost	$ 173,600

a. U.S. Army Corps of Engineers, "Preliminary Recreation Reconnaissance, Calapooia River, Holley Dam Site," Undated. Received 24 July 1965.

b. U.S. Army Corps of Engineers, "Reconnaissance of Holley and Thomas Creek Dam Sites with Bureau of Outdoor Recreation Personnel," NPPEN-PP-3, 15 February 1965.

To fully investigate the complementary and competitive aspects of water storage for water quality control, full recreation development was assumed. Maintenance, operation, and replacement costs were assumed to be twice amortization costs in the simulation model.

APPENDIX V

FLOW DIAGRAMS OF COMPUTER PROGRAMS

by D. J. Hinrichs

To simulate the hydrologic conditions and economic response to potential water resource systems in the Calapooia Basin, a daily flow simulator was deemed essential. This simulator was developed and tested in FORTRAN on a Control Data Corporation (CDC) 6600 computer.

DYNAMO appeared better suited to accomplish the aims of this research project and consequently the hydrologic and water-related economic systems of the Calapooia Basin were simulated, tested, and analyzed by this program. Printout from the final simulation model revealed the ability of potential designs to meet target outputs, identify critical shortages, and report any excesses. The complementary and competitive aspects of water storage for water quality control were easily identified and analyzed from the results.

Contained in this appendix are flow diagrams which provide an explanation of the DYNAMO and FORTRAN computer programs.

SUMMARY OF DYNAMO PROGRAM

I. Hydrologic Simulation

- A. Day, season, and year counters (DC 1-4, SK 1-4, YC 1-2)*
- B. Upstream hydrology (UH 1-242)
- C. Downstream hydrology (DH 1-258)
- D. Generation of low flows only, Willamette River Hydrology (WH 1-30)
- E. Flows into the Willamette River (FW 1-8)

II. Reservoir Routing

- A. Reservoir and channel level (RCL 1-12)
- B. Reservoir releases (RR 1-243)
- C. Routing Analysis (RA 1-11)

III.
- A. Drainage benefit (DB 1-12)
- B. Flood loss (FL 1-18)
- C. Flood benefit (FBC 1-16)
- D. Irrigation return flow (IR 1-4)
- E. Irrigation benefit (IB 1-9)
- F. Fish benefits and costs (FB 1-28)
- G. Water quality benefits (WQ 1-13)
- H. Recreation benefits (RB 1-19)
- I. Recreation costs (RC 1-4)
- J. Structure sizes (SS 1-5)
- K. Net benefits (NB 1-16)
- L. Costs (C 1-13)
- M. Capital recovery factors (CR 1-12)

* Location of each section given in parentheses.

IV. Output Analysis

   A. Maximum and minimum annual reservoir levels (E 1-41)

   B. Flood loss distribution (E 42-63)

   C. Irrigation (E 64-70)

   D. Minimum channel flow and conservation pool (E 71-87)

   E. Water quality (E 88-97)

   F. Recreation attendance (equals recreation benefit)(E 98-107)

   G. Sum of annual flows (FA 1-20)

   H. Spill data (SP 1-6)

   I. Maximum and minimum daily flows (DF 1-8)

   J. Fish release (FR 1-5)

V. Economic Analysis and Shortage Indices

   A. Drainage loss and shortage index (SI 1-10)

   B. Channel shortage index (flood control)(SI 11-19)

   C. Flood storage shortage index and Willamette River flood losses (SI 20-28)

      1. Channel storage

      2. Reservoir storage

   D. Irrigation loss and shortage idex (SI 29-36)

   E. Fish loss and shortage index (SI 37-67)

   F. Water quality loss and shortage index (SI 68-87

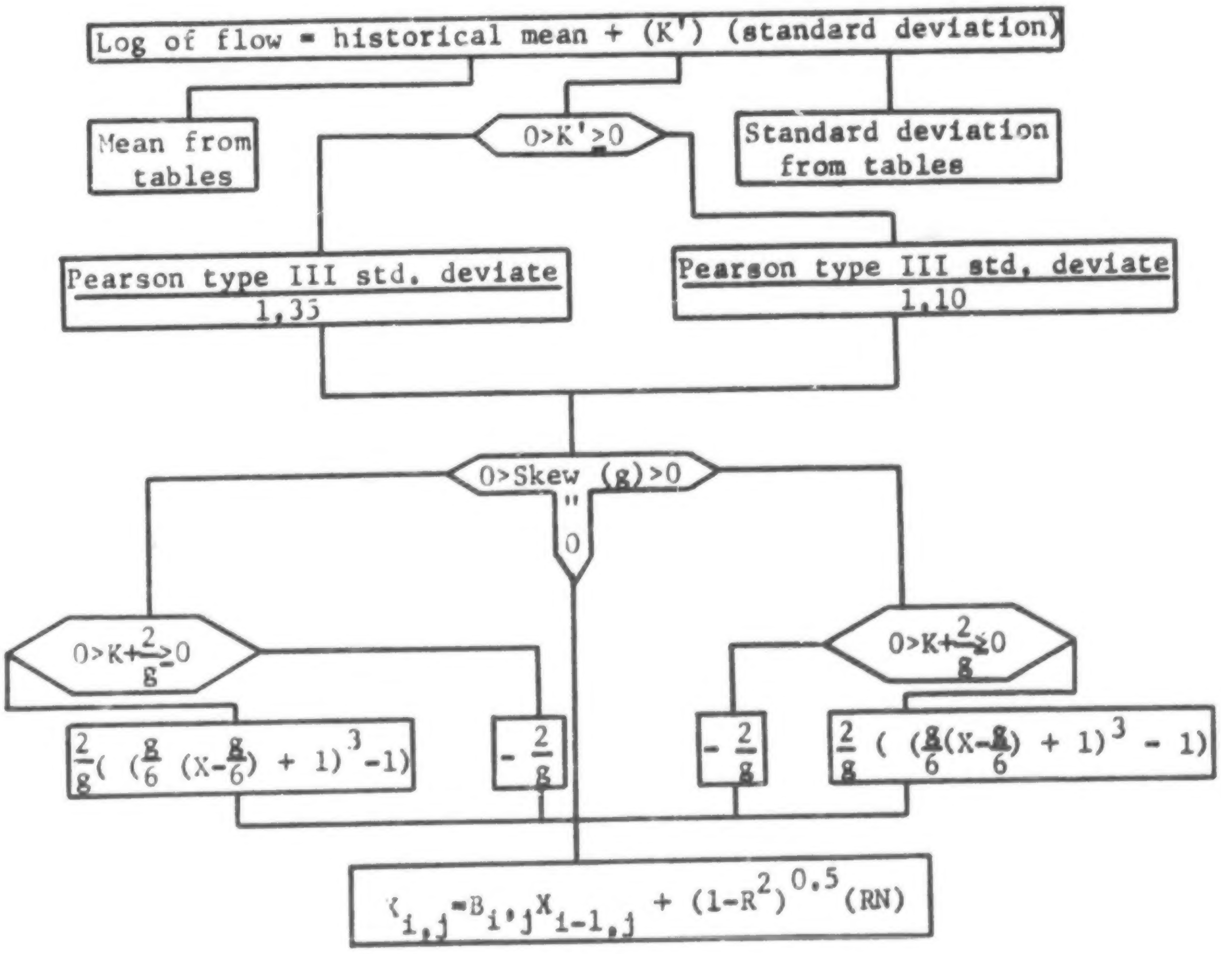
   G. Recreation loss and shortage index (SI 88-99)

DYNAMO FLOW DIAGRAM

I. Hydrologic Simulation

A. Day, Season, and Year Counters
These counters are used to identify moments in time during the simulation runs. Various demands occur on different days during the year. Season counters were required in the hydrologic simulation model to overcome space limitations in the table functions of the DYNAMO program used in this project.

B. Upstream Hydrology
(Simulation of flow into reservoir)



Log of flow = historical mean + (K') (standard deviation)
Mean from tables
$0>K'\geq 0$
Standard deviation from tables
Pearson type III std. deviate 1.35
Pearson type III std. deviate 1.10
$0>\text{Skew }(g)>0$
$=$
0
$0>K+\frac{2}{g}\geq 0$
$0>K+\frac{2}{g}\geq 0$
$\frac{2}{g}((\frac{g}{6}(X-\frac{g}{6})+1)^3-1)$
$-\frac{2}{g}$
$-\frac{2}{g}$
$\frac{2}{g}((\frac{g}{6}(X-\frac{g}{6})+1)^3-1)$
$X_{i,j}=B_{i,j}X_{i-1,j}+(1-R^2)^{0.5}(RN)$

C. Downstream Hydrology
Downstream flows are generated using equations and flow diagrams similar to the upstream flow, with the following changes:

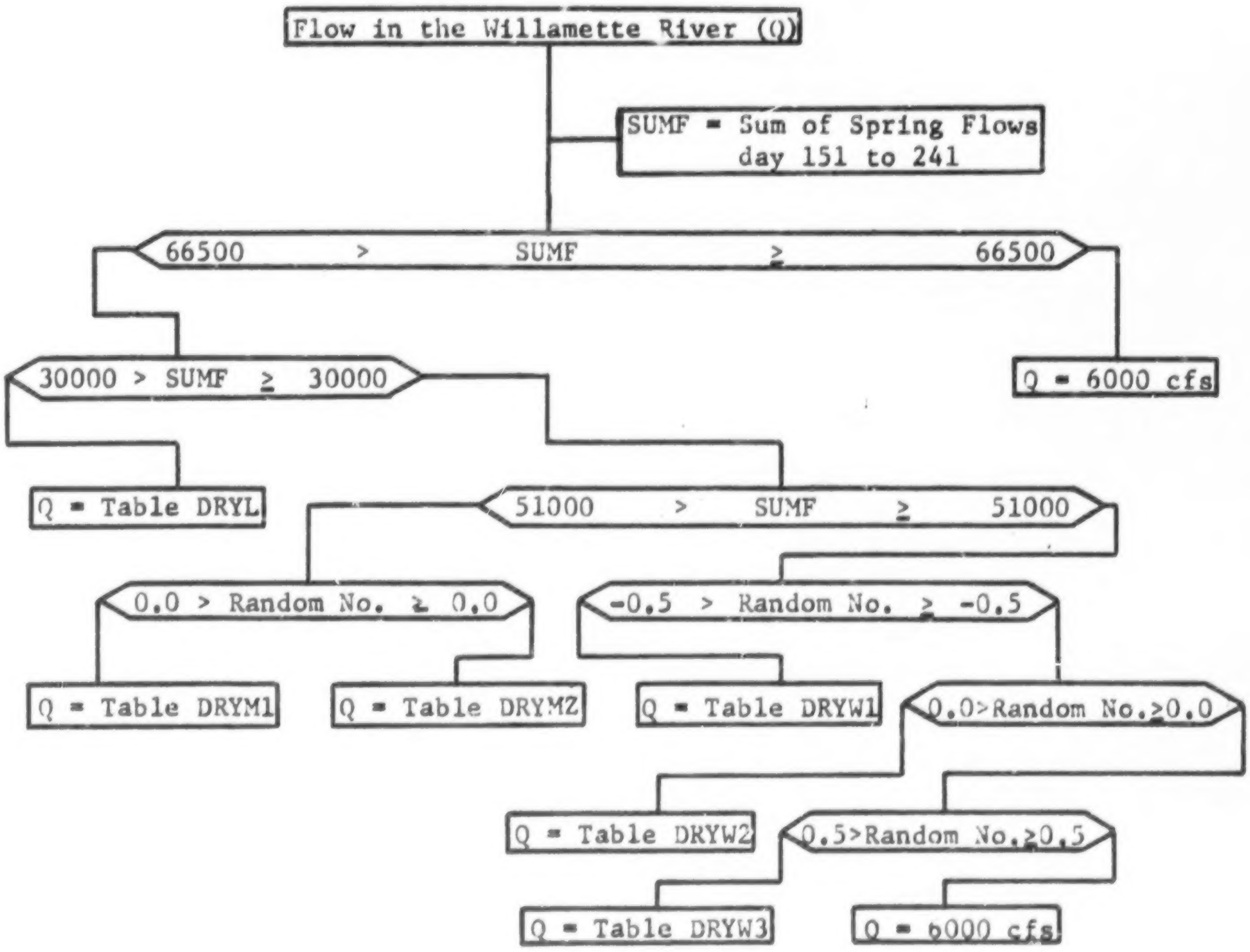
1. Coefficient C,

a. If $K' \geq 0$, change 1.1 to 1.2

b. If $K' < 0$, change 1.35 to 1.45

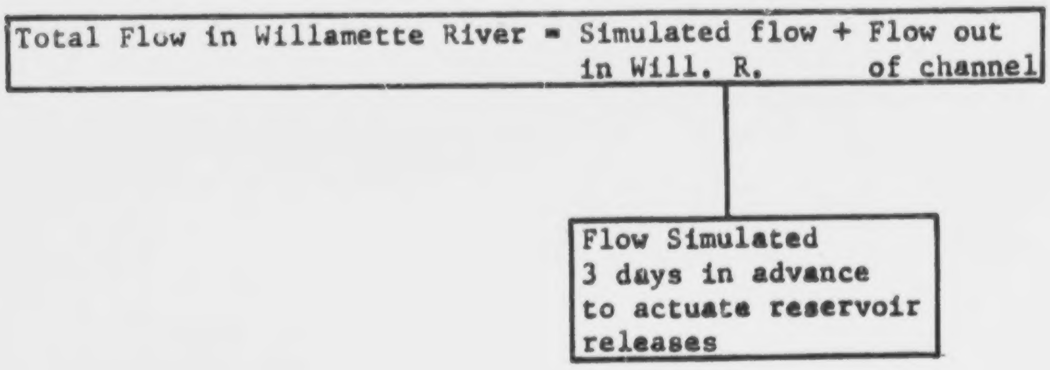
2. X, $X_{i,j} = B_{i,j} X_{i-1,j} + B_{i,j} X_{i,j-1} + (1-R^2)^{0.5}(RN)$

D. Generation of Low Flows Only, Willamette River Hydrology
(Flow augmentation not requested if Q is equal to or greater than 6000 cfs)


Flow in the Willamette River (Q)
SUMF = Sum of Spring Flows day 151 to 241
66500 > SUMF ≥ 66500
30000 > SUMF ≥ 30000
Q = 6000 cfs
Q = Table DRYL
51000 > SUMF ≥ 51000
0.0 > Random No. ≥ 0.0
-0.5 > Random No. ≥ -0.5
Q = Table DRYM1
Q = Table DRYM2
Q = Table DRYW1
0.0>Random No.≥0.0
Q = Table DRYW2
0.5>Random No.≥0.5
Q = Table DRYW3
Q = 6000 cfs

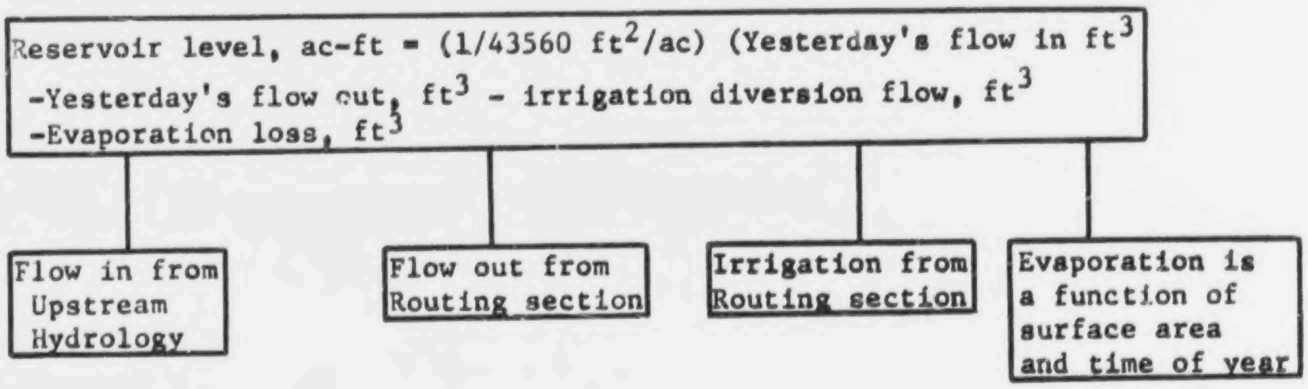
Tables contain routed summer flows through authorized system, less project flows in Willamette River for dry years based on historical data from 1926 through 1955.

E. Flows into the Willamette River


Total Flow in Willamette River = Simulated flow in Will. R. + Flow out of channel
Flow Simulated 3 days in advance to actuate reservoir releases

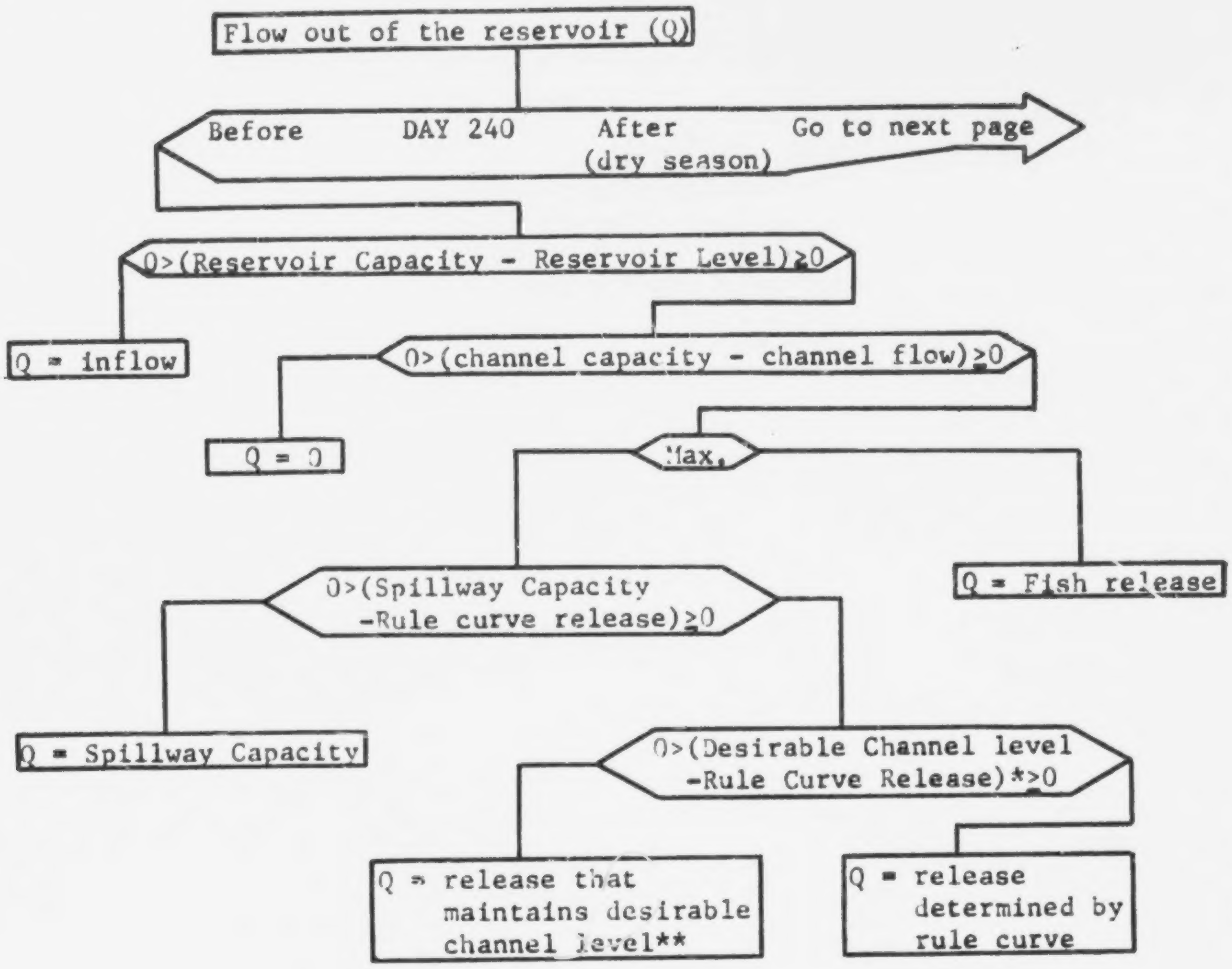
II. Reservoir Routing

A. Reservoir and Channel Level


Reservoir level, ac-ft = (1/43560 ft²/ac) (Yesterday's flow in ft³ -Yesterday's flow out, ft³ - irrigation diversion flow, ft³ -Evaporation loss, ft³
Flow in from Upstream Hydrology
Flow out from Routing section
Irrigation from Routing section
Evaporation is a function of surface area and time of year

Channel level = Previous channel level + Previous reservoir release + simulated channel flow - previous inflow to reservoir + irrigation return flow - flow out of channel.

B. Reservoir Releases


Flow out of the reservoir (Q)
Before
DAY 240
After
(dry season)
Go to next page
Q>(Reservoir Capacity - Reservoir Level)≥0
Q = inflow
Q>(channel capacity - channel flow)≥0
Q = 0
Max.
Q = Fish release
Q>(Spillway Capacity -Rule curve release)≥0
Q = Spillway Capacity
Q>(Desirable Channel level -Rule Curve Release)*>0
Q = release that maintains desirable channel level**
Q = release determined by rule curve

* Rule Curve Release - This is the release determined by reservoir rule curve.

** Desirable Channel Level = Channel capacity - safety factor
Safety factor determined by marginal analysis to minimize flood damage to channel and still maintain capacity in reservoir for flood storage.

Flows from the reservoir during the dry season are released on a priority basis determined by the analytical model and are a function of the volume available to meet the remaining demand, and the expected inflow during the remainder of the season.

Priority No. 1 stores water available above a dead storage level of 20,000 ac-ft for temperature control for the downstream fishery, plus additional water for water quality control. The stored water also contributed to reservoir sport fish and recreation benefits.

Volume of water after Priority No. 1 is met (Volume No. 1) =

Reservoir level + Expected inflow remainder of dry season

- 60% minimum conservation pool for temperature control
- 60% Volume for downstream fish release
- Increments No. 1 & 2 Water quality demand in excess of fish releases

If Volume No. 1 is negative, allocate expected available volume of water proportionally between downstream fish release and minimum conservation pool. The objective is to have the percent target met for both the fish flow and reservoir level for temperature control as high as possible to maximize anadromous fish enhancement. Fishery releases will complement water quality benefits.

If Volume No. 1 is positive, allocate Volume No. 1 to meet remaining demands.

Priority No. 2 stores 80% of the remaining irrigation demand, which is released on a daily basis according to varying demands during the irrigation season.

Volume of water remaining after priority No. 2 is met (Volume No. 2)	=	Volume No. 1 - 80% of remaining irrigation demand.

If Volume No. 2 is negative, allocate expected available volume proportionally to irrigation demands during the remainder of the irrigation season.

If Volume No. 2 is positive, allocate Volume No. 2 to meet remaining demands.

Recreation and reservoir sport fisheries also benefit from stored water.

Volume of water remaining after Priority No. 3 is met (Volume No. 3) =

Volume No. 2 - Remaining 40% of conservation pool

- Remaining 40% of fish demand (reduced if water previously allocated for water quality control)

If Volume No. 3 is negative, allocate expected available volume proportionally between downstream fish release and minimum conservation pool.

If Volume No. 3 is positive, allocate Volume No. 3 to meet remaining demands.

Priority No. 3 stores water for temperature control for the downstream fishery and releases water for the downstream fishery.

Priority No. 3 stores the 20% of the remaining irrigation demand, which is released on a daily basis according to varying demands during the irrigation season.

Volume of water remaining after Priority No. 4 is met (Volume No. 4) = Volume No. 3 - 20% of remaining irrigation demand

If Volume No. 4 is negative, allocate the expected available volume proportionally to irrigation demands during the remainder of the irrigation season.

If Volume No. 4 is positive, allocate Volume No. 4 to meet remaining demands.

Priority No. 5 stores 20% of the minimum conservation pool volume for recreation and reservoir sport fish.

Volume of water remaining after Priority No. 5 is met (Volume No. 5) = Volume No. 4 - 20% minimum conservation pool

If Volume No. 5 is negative, store the volume available (Volume No. 4).

If Volume No. 5 is positive, allocate Volume No. 5 to meet remaining demands.

Priority No. 6 stores water for third increment of water quality demand, which is released on a daily basis according to varying demands during the dry season.

Volume of water remaining after Priority No. 6 is met (Volume No. 6) = Volume No. 5 - Water quality demand, Increment No. 3

If Volume No. 6 is negative, allocate expected available volume proportionally to the water quality demand (third increment) during the dry season.

If Volume No. 6 is positive, allocate Volume No. 6 to meet remaining demands.

Priority No. 7 stores water for the fourth and final increment of water quality demand, which is released on a daily basis.

Volume of water remaining after Priority No. 7 is met (Volume No. 7) = Volume No. 6 - Water quality demand, Increment No. 4

If Volume 7 is negative, allocate expected available volume proportionally to the final increment of water quality demand during the dry season.

If Volume No. 7 is positive, store Volume No. 7 for recreation.

Water quality demand is divided into four increments on the basis of the incremental value ($/ac-ft) of the released water's contribution to the net benefits. The incremental value is a function of the simulated Willamette River hydrograph. The more water required to increase the minimum flow, the less the incremental value. Each demand increment is determined in a manner similar to the procedure used for Generation of Low Flows, Willamette River Hydrology Section. Whereas the tables in the Willamette River Hydrology Section define the low flows, the tables for water quality demand give the releases required to increase these flows to attain the target flow for water quality control (fourth increment will increase flow in the Willamette River to 6000 cfs if release demands are met). Since releases for the downstream fishery complement low flow augmentation for water quality, the water quality demand tables consider the amount released for the fishery. In some cases the fish release will fulfill the first two increments of water quality demand.

C. Routing Analysis

The day of the maximum reservoir level, days of maximum three-day flow, and day of minimum reservoir level are found and recorded in this section. Day of the maximum reservoir level is found for the winter flood control (prior to day 182) and for the entire year to aid the preparation of a filling schedule to achieve maximum storage to meet summer demands. These procedures simply compare today's level or flow with the maximum to date. This is repeated for the time period under consideration.

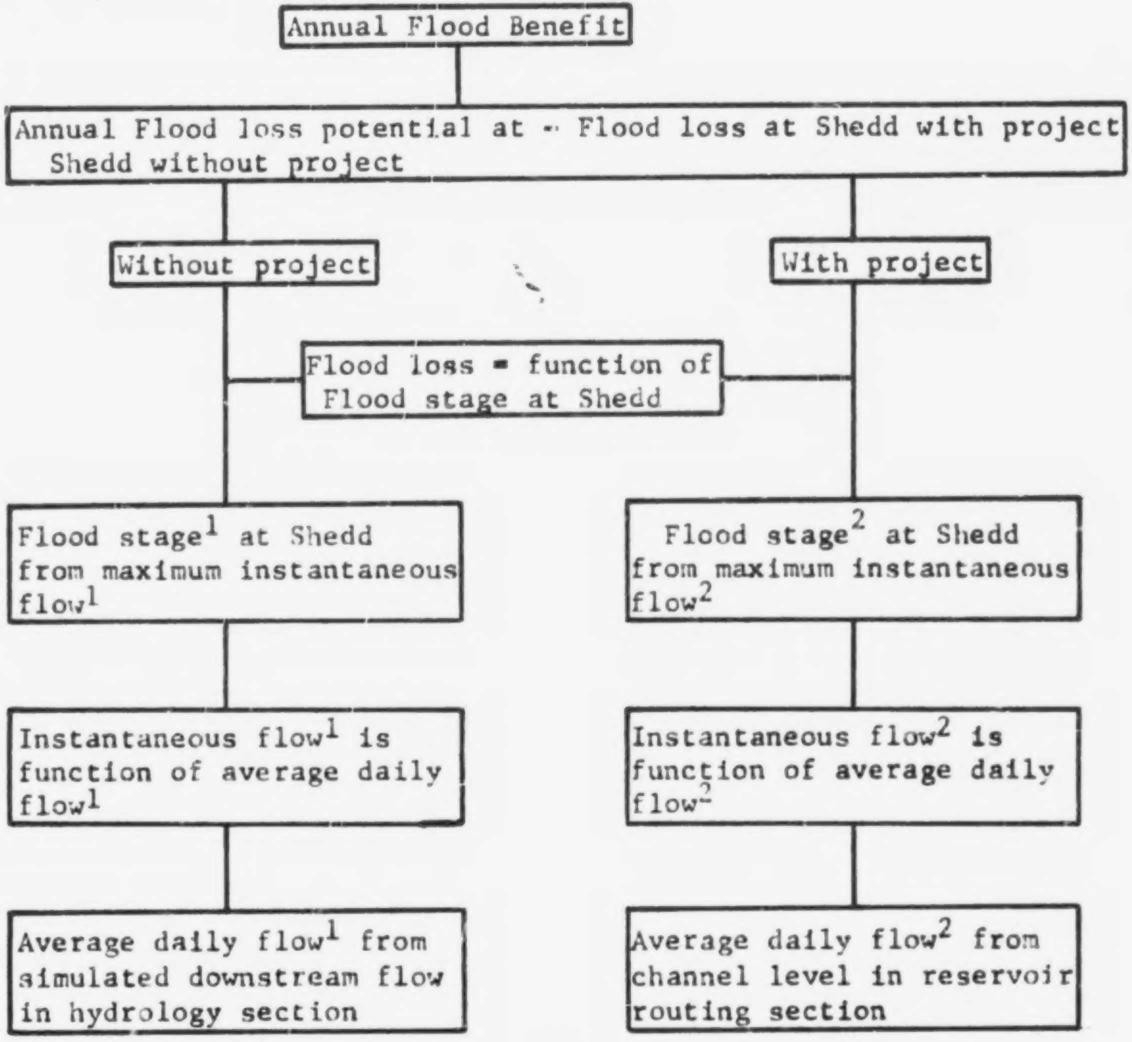
III. Economic Model

A. Drainage Benefit = (% drainage target output met) x (total annual benefit)

The % target met is a function of the channel level. If the average channel level is less than 30% of the channel capacity during the drainage season (Spring), then 100% of the target is met. As the average channel level increases from 30 to 60%, the drainage benefit decreases from 100 to 40% of the target benefit. If the average channel level increases from 60 to 100%, then the drainage target benefit decreases from 40 to 0%

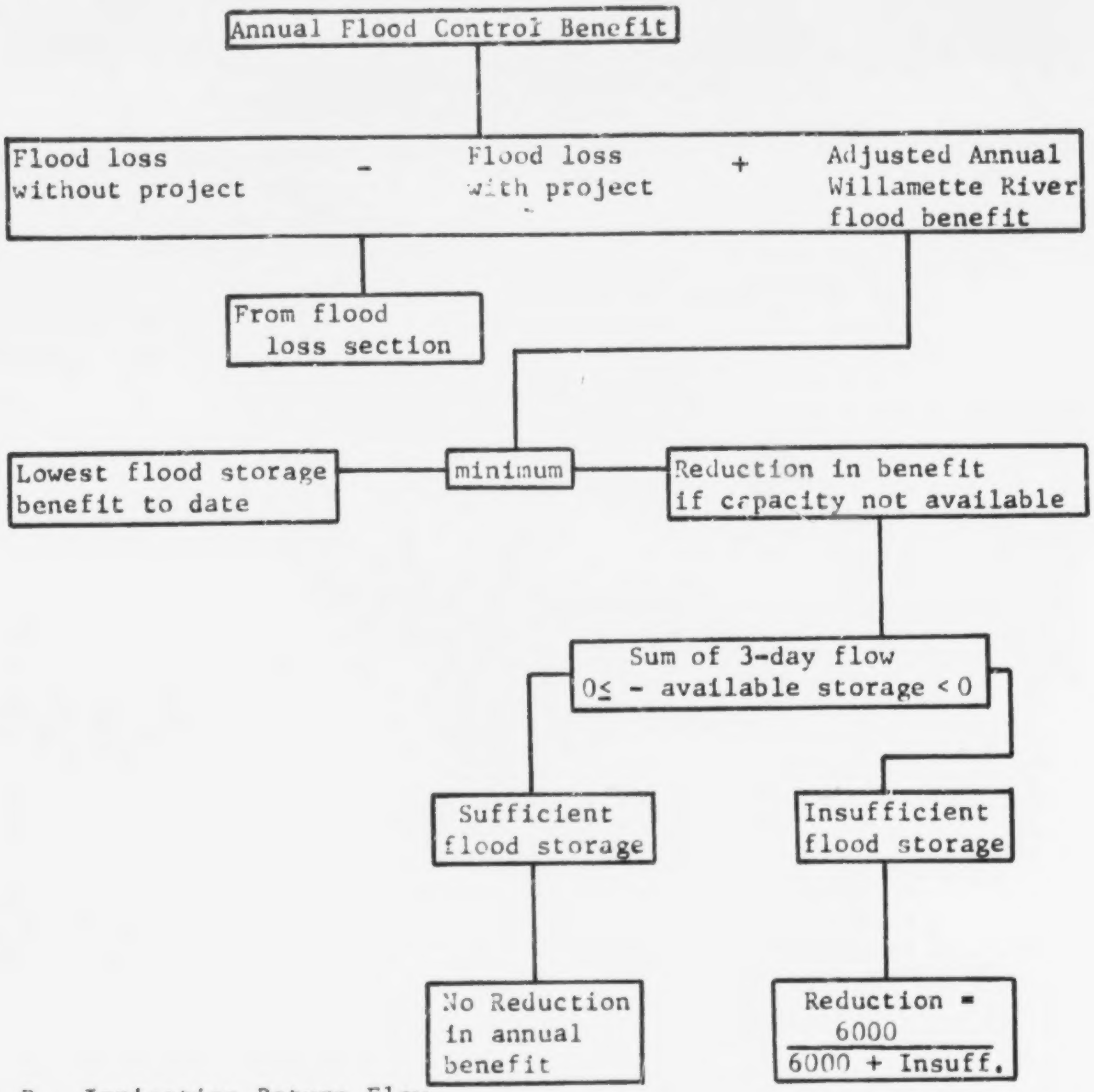
The total annual benefit is a function of the channel capacity. As the channel capacity is increased from 5000 to 21000 cfs, the total annual benefit (possible) increases from 0 to $500,000 as shown in the program.

B. Flood Loss


Annual Flood Benefit
Annual Flood loss potential at Shedd without project - Flood loss at Shedd with project
Without project
With project
Flood loss = function of Flood stage at Shedd
Flood stage¹ at Shedd from maximum instantaneous flow¹
Flood stage² at Shedd from maximum instantaneous flow²
Instantaneous flow¹ is function of average daily flow¹
Instantaneous flow² is function of average daily flow²
Average daily flow¹ from simulated downstream flow in hydrology section
Average daily flow² from channel level in reservoir routing section

Superscript 1 refers to conditions without the project.
Superscript 2 refers to conditions with the project.

C. Flood Benefit


Annual Flood Control Benefit
Flood loss without project
-
Flood loss with project
+
Adjusted Annual Willamette River flood benefit
From flood loss section
Lowest flood storage benefit to date
minimum
Reduction in benefit if capacity not available
Sum of 3-day flow 0≤ - available storage < 0
Sufficient flood storage
Insufficient flood storage
No Reduction in annual benefit
Reduction = 6000 / 6000 + Insuff.

D. Irrigation Return Flow

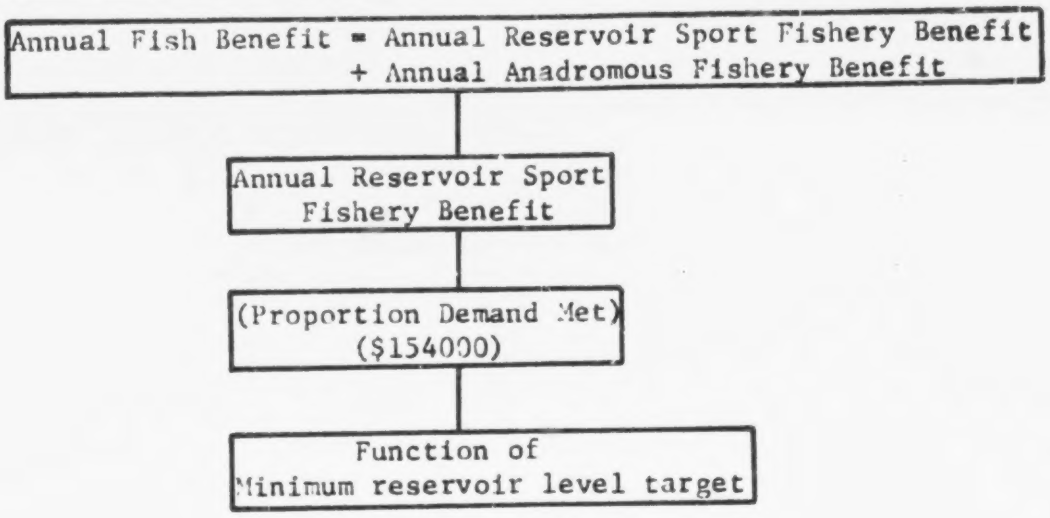
This section calculates the irrigation return flow which equals 15% of the irrigation release. Irrigation release is determined in the routing section.

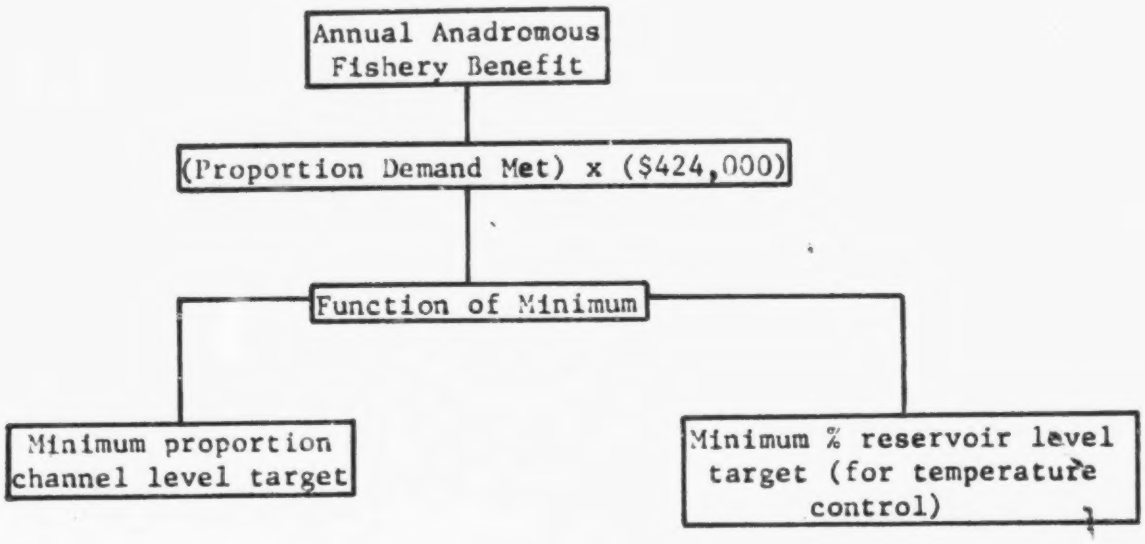
E. Irrigation Benefit

Annual Irrigation Benefit = (% irrigation target benefit met) x (total benefit)

Irrigation benefits depend on the ability of the system to meet the target output. The irrigation loss function is determined from percentage of the irrigation target output met.

F. Fish Benefits and Costs


Annual Fish Benefit = Annual Reservoir Sport Fishery Benefit
+ Annual Anadromous Fishery Benefit
Annual Reservoir Sport Fishery Benefit
(Proportion Demand Met) ($154000)
Function of Minimum reservoir level target


Annual Anadromous Fishery Benefit
(Proportion Demand Met) x ($424,000)
Function of Minimum
Minimum proportion channel level target
Minimum % reservoir level target (for temperature control)

Annual fish cost = (Initial fish cost) x (50-year capital recovery factor

+ .10 for M & O)

G. Water Quality Benefit

$$\text{Annual water quality benefit} = \left[\begin{array}{l} \text{(Minimum proportion water quality flow objective met)} \times \text{(water quality benefit (annual M \& O saving))} \\ + \text{(20-year capital recovery factor)} \times \text{(Initial plant cost saving)} \end{array} \right.$$

Annual benefits are actually savings obtained from initial and annual treatment costs (M & O) not required due to anticipated flow augmentation target. The minimum flow objective in the Willamette River is 6000 cfs. A maximum flow augmentation release of 1500 cfs would be required from the reservoir during the most critical low flow periods. The minimum % water quality flow objective met = (minimum flow, cfs - 4500 cfs) divided by (water quality objective, cfs - 4500 cfs).

H. Recreation Benefit

Annual recreation benefit = accumulated daily recreation attendance @ $1 per person from day 240 to day 350 (Summer recreation season)

The attendance is a function of reservoir level which is converted to the distance from high water level to actual water surface.

I. Recreation costs

Annual recreation cost = (3)* x (initial cost)(50-year capital recovery factor)

*M & O = 2 times amortized cost

J. Structure sizes

Structural inputs include channel capacity and reservoir capacity.

K. Net Benefits

Annual net benefits = the sum of annual benefits - the sum of annual costs

The annual benefits were calculated in the previous sections.

Most of the annual costs also were calculated in the previous sections, while the remainder are calculated in the next section.

The average annual net benefits are found by dividing cumulative sum of net benefits by the number of years of concern.

A measure of the uncertainty associated with any proposed system is the standard deviation of the net benefits and is calculated as follows:

$$\text{Standard Deviation} = \text{Square Root}\left[\frac{\text{Sum of squared net benefits} - \dfrac{\text{Sum of net benefits squared}}{\text{No. of years}}}{\text{Number of years} - 1}\right]$$

L. Costs

Annual Reservoir Cost = Initial reservoir cost amortized over 100 years

The initial reservoir cost is a function of reservoir capacity.

Initial irrigation cost = initial cost for 69,900 ac.ft target output adjusted by new irrigation target factor.

New irrigation target factor is ratio of new target over 69,900 when target is below 69,900 and ratio square when target is above 69,900

Annual cost for 69,900 ac.ft output = 1.075* multiplied by the initial irrigation cost

* Irrigation M & O = 7.5% of amoritized costs.

Drainage cost = 1.1* multiplied by the initial cost amortized over 100 years

The initial cost is a function of channel capacity

* M & O = 10% of amortized costs

M. Capital Recovery Factors

$$\boxed{\text{C.R.F.} = \frac{\text{interest rate } (1 + \text{interest rate})^n}{(1 + \text{interest rate})^n - 1}}$$

where n = number of years. Capital recovery factors are calculated for 20, 50, and 100 years.

IV. Output Analysis

A. Maximum and minimum annual reservoir levels

The annual maximum reservoir level is determined and counters sum the number of times the reservoir level exceeds 90, 95, 98, 99.5, and 100 percent of the reservoir capacity on an annual basis. The annual minimum reservoir level is also found. The number of times the minimum reservoir level is 90, 98, 105, and 115 percent of the minimum conservation pool of 51,000 ac.ft is determined.

The frequency of meeting 80, 90, and 100 percent of the drainage target is counted in this section, too. The drainage target is a function of the channel capacity as shown in the drainage benefit section.

B. Flood Loss Distribution

The maximum annual instantaneous channel flows with and without the project are calculated. Counters determine the number of times that the flow exceeds 11,000, 16,000, 20,000, 21,000, and 25,000 cfs.

C. Irrigation

Counters in this section sum the number of times that 80, 90, and 100 percent of the irrigation target is met.

D. Minimum Channel Flow and Conservation Pool

The percent minimum channel flow target is calculated, based on minimum release flows and target flow for downstream fisheries. The annual frequency of percent minimum flow exceeding 80, 90, 99.9, and 120 percent of the minimum target requirement is determined. The number of times that the percent minimum reservoir target level exceeds 80, 90, 99.9, and 120 percent (necessary for reservoir fishery and for temperature control for downstream fishery) is recorded also.

E. Water Quality

This section counts the frequency of meeting 50, 80, 90, 100, and 120 percent of the minimum water quality target flow of 6000 cfs in the Willamette River at Salem, Oregon.

F. Recreation Attendance

The number of times that the recreation attendance exceeds 450,000, 480,000, 500,000, 520,000, 550,000 people is determined in this section. This equals the recreation benefit since the value of recreation is assumed to be $1 per visitor-day.

G. Sum of Annual Flows

The simulated flows into the reservoir and in the channel are summed and the maximum reservoir levels for each season are recorded.

H. Spill Data

The annual volume spilled and the number of years when water was spilled are calculated.

I. Maximum and Minimum Daily Flows

This section is used to calculate maximum and minimum flow into the reservoir and channel.

J. Fish Release

This section sums the additional release of water for fish above the actual inflow to the reservoir. This volume represents the amount contributed by the reservoir to maintain minimum fish flows.

V. Economic Analysis and Shortage Indices

A. Drainage Loss and Shortage Index

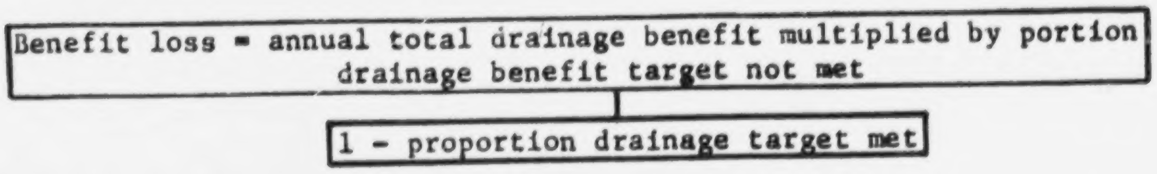
Drainage shortage index = Proportion drainage shortage squared

drainage shortage (excess flow) / 0.3*

average proportion channel level full - 0.3

* If average channel flow during drainage season is less than 30% of the channel capacity, then the drainage target is achieved.

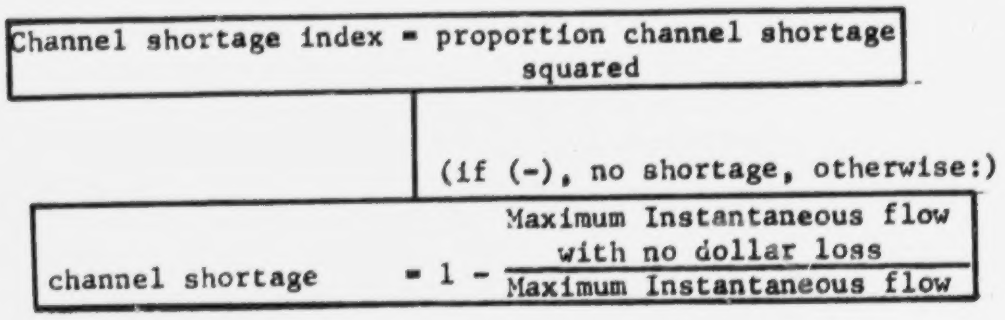
Dollar loss from drainage shortage



Benefit loss = annual total drainage benefit multiplied by portion drainage benefit target not met

1 - proportion drainage target met

B. Channel Shortage Index (flood control)



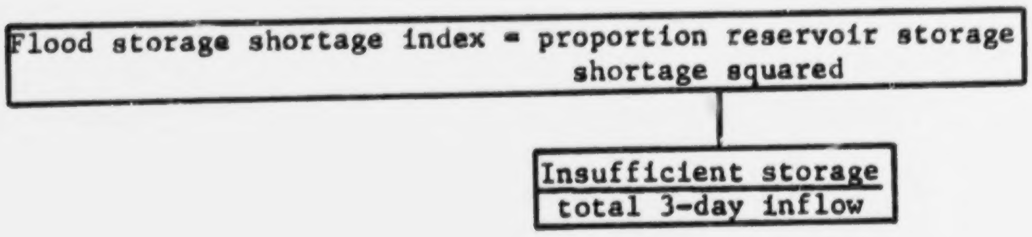
Channel shortage index = proportion channel shortage squared

(if (-), no shortage, otherwise:)

$$\text{channel shortage} = 1 - \frac{\text{Maximum Instantaneous flow with no dollar loss}}{\text{Maximum Instantaneous flow}}$$

Annual channel flood loss calculated in flood loss section of the model (III - B).

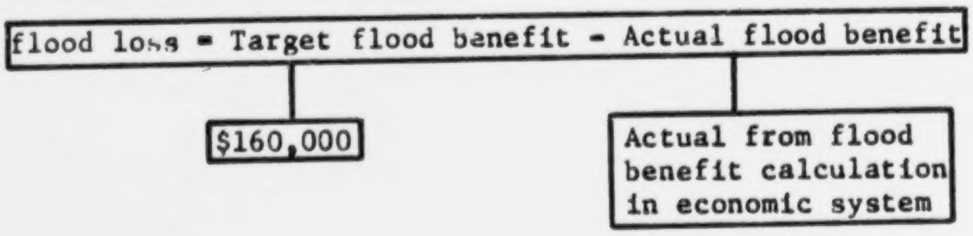
C. Flood Storage Shortage Index and Willamette River Flood Losses



Flood storage shortage index = proportion reservoir storage shortage squared

$$\frac{\text{Insufficient storage}}{\text{total 3-day inflow}}$$

Willamette River flood loss

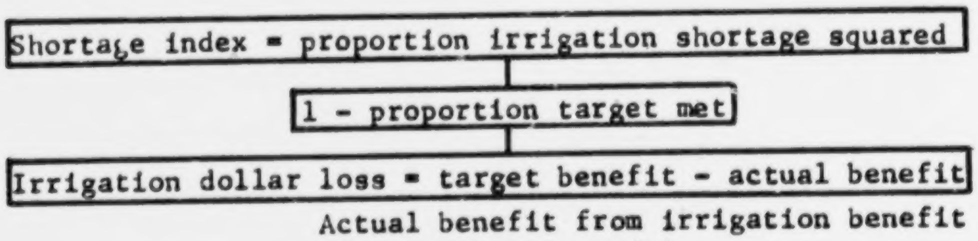


flood loss = Target flood benefit - Actual flood benefit

$160,000

Actual from flood benefit calculation in economic system

D. Irrigation Loss and Shortage Index and Losses



Shortage index = proportion irrigation shortage squared

1 - proportion target met

Irrigation dollar loss = target benefit - actual benefit

Actual benefit from irrigation benefit section of the economic model.

E. Fish Loss and Shortage Index

Downstream release shortage index = proportion downstream release shortage squared

$$1 - \frac{\text{total fish release} + 130\ \text{std*}}{\text{total fish demand}}$$

130 cfs release required due to DYNAMO summation procedure.

Shortage index for reservoir sport fish and temperature control for anadromous fish downstream = Proportion of shortage squared (if (+) otherwise zero)

$$1 - \frac{\text{minimum reservoir level}}{\text{minimum conservation pool}}$$

Dollar loss for anadromous fish due to loss of reservoir temperature control and insufficient channel flow.

Loss = Target benefit - actual benefit

Target benefit: $424,000

Actual benefit: (proportion target met) (target benefit)

Dollar losses for anadromous fish (insufficient channel flow)*, anadromous fish (temperature control in the reservoir)*, and reservoir sport fish are calculated in the same manner as above.

* These values were calculated separately to test the ability of the allocation procedure to distribute flows equitably.

F. Water Quality Loss and Shortage Index

Shortage index = proportion shortage squared

$$1 - \frac{\text{demand} + \text{flow shortage}}{\text{demand}}$$

The demand is from the routing section

Flow shortage = flow objective - actual minimum flow into Willamette River

Dollar loss = (1 - proportion water quality met) (water quality benefit)

G. Recreation Shortage Index

Shortage index = proportion shortage squared

$$1 - \frac{\text{average reservoir level}}{\text{reservoir capacity}}$$

(calculated for period from day 240 to day 350 only)

Dollar loss = $550,000 - accumulated recreation benefit

PRINT CARD

Many different print cards were used throughout this project. Every section of the simulation model was tested on a daily basis for 730 days and all calculations by the computer were checked to be sure the model was performing as intended. During searches for optimum conditions only, the final results in terms of average annual net benefits and the standard deviation were printed. At optimum conditions and other combinations of inputs, target outputs, and operational procedures of interest, the performance of the design under consideration was analyzed in detail at the end of each year. To give an indication of the information collected, the symbols on a print card will be explained.

Column 1

YEARS - Number of years from beginning of simulation run.

SUM3 - Sum of inflows to reservoir during 3 months before low flow demand period. Used with CURN to select a low flow hydrograph for Willamette River at Salem and to predict expected summer inflow to reservoir.

CURN - Constant. A uniformly distributed random number from -1.0 to 1.0 that is generated once a year and is used with SUM3 to select a low flow hydrograph for the Willamette River at Salem.

ASFR1 - Annual sum of slows into reservoir. (Upstream Simulation Station).

ASFC2 - Annual sum of flows in channel. (Downstream simulation station).

MXRLC - Maximum Reservoir Level Counter is the maximum reservoir level for the year. It also is used to count the number of times the reservoir exceeds specified levels.

RE900, RC950, RC980, and RC995 - Reservoir counters. They count the number of years that the reservoir level exceed 90, 95, 98 and 99.5 percent capacity.

Column 2

RCCAP - Counts the number of years the reservoir capacity is exceeded.

MIRLC - Minimum Reservoir Level Counter is the minimum reservoir level for the year. It also is used to count the number of times the reservoir exceeds specified levels.

RC115, RC105, RCCPL, RC098, RC090 - Reservoir counters. They count the number of years that the minimum reservoir level exceeds 105, conservation pool, 98 and 90% of the minimum conservation pool.

PRCLV - Percent average channel level during drainage period. Used to determine percent annual drainage target benefit achieved.

PDTM - Percent drainage target met.

ADBR - Annual drainage benefit received.

Column 3

DG100, DG90, DG80 - Counts number of years percent drainage target was equal to or greater than 100, 90, and 80 percent.

MXACC - Maximum actual instantaneous flow in channel during year.

AFLD1 - Annual flood benefit.

CAC11, CAC16

Column 4

CAC20, CCC21, CAC25 - Counts number of years actual instantaneous channel flows exceeded 11, 16, 20, 21 (capacity), and 25,000 cfs.

CPC11, CPC16, CPC21, CPC25. Counts number of years flow potentially will exceed 11, 16, 20, 21, and 25,000 cfs with project.

NIRGT - New irrigation target. Used to adjust irrigation demands, costs, and benefits from a base target of 69,900 ac-ft.

TIRO - Total irrigation release out of reservoir, ac-ft.

Column 5

PITM - Percent irrigation target met.

ANIBH - Annual irrigation benefit.

IG100, IG90, IG80 - Counts number of years percent irrigation target met is equal to greater than 100, 90, and 80 percent of target.

MIPCF - Minimum percent channel flow for fishery enhancement. Percentage is calculated on basis of minimum channel flow and minimum target flow for fishery.

CG120, CG100, CG90, CG80 - Counts number of years minimum channel flow was equal to or greater than 120, 100, 90, and 80 percent of the minimum target flow.

Column 6

MIPCP - Minimum percent conservation pool. Used to evaluate temperature control objective.

PG120, PG100, PG90, PG80 - Counts number of years minimum was equal to or greater than 120, 100, 90, and 80 percent of the minimum target conservation pool.

PFBRS - Percent fish benefit for reservoir sport fishery.

FIBRS - Annual fish benefit for reservoir sport fishery.

PFBAD - Percent fish benefit for anadromous fish.

FIBAD - Annual fish benefit for anadromous fish.

FB - Total annual fishery benefit, FIBRS + FIBAD

Column 7

MIFWR - Percent minimum flow target in Willamette River

PWQB - Percent water quality benefit.

WAQB - Annual water quality benefit.

MIPQW - Minimum percent water quality target

WG120, WG100, WG90, WG80, WG50 - Counts number of years water quality exceeded 120, 100, 90, 80, and 50 percent of target output.

AREC - Accumulated daily recreation attendance for year.

Column 8

RCB - Annual recreation benefit.

RAC45, RAC48, RAC50, RAC52, RAC55 - Counts the number of years annual recreation benefits exceeded 450, 480, 500, 520, and 550,000 dollars.

SP4 - Records volume of water spilled from reservoir during year, ac-ft.

SPCTS - Counts the number of years water spilled from reservoir.

SUMBN - Sum of benefits during year.

SUMCT - Sum of costs during year.

Column 9

NETBN - Annual net benefits.

SUNET - Sum of annual net benefits.

SSNET - Sum of squares of annual net benefits.

MADR - Maximum average daily flow into reservoir during year.

MNR - Minimum average daily flow into reservoir during year.

MADC - Maximum average daily flow into channel during year.

MNC - Minimum average daily flow in channel during year.

ERS12 - Difference between expected summer inflow to reservoir and sum inflow to dam. Expected summer inflow to reservoir used to allocate water during low flow period.

DAMRL - Day maximum reservoir level. Used in determining rule curve during flood season.

DAM3D - Day of maximum 3 day flow into reservoir. Used to determine maximum flood storage volume.

Column 10

MXLS1, MXLS2, MXLS3, MXLS4 - Maximum level of reservoir during season 1, 2, 3, and 4.

ADRF1 - Additional release for fish. Volume of water released to meet minimum downstream fish demands above flows available without project.

SIDR - Shortage index for drainage.

DRBL - Sum of drainage benefit losses.

SICH - Shortage index for channel. (Flood control).

FDLR2 - Sum of channel flood losses.

Column 11

WRFL - Sum of Willamette River flood losses from insufficient reservoir storage.

SIIR - Shortage index for irrigation

IRL - Sum of irrigation losses.

SIFD - Shortage index for fish demand (downstream flows)

SIFR - Shortage index for reservoir sport fishery.

FADL - Sum of anadromous fish losses from shortages in channel (low flows) and reservoir (temperature control).

FADC - Sum of anadromous fish losses from insufficient channel flows.

FADS - Sum of anadromous fish losses from insufficient reservoir storage to maintain temperature control.

SIWQ - Shortage index for water quality.

WQL - Sum of water quality losses.

Column 12

TWQRL - Total water quality release during year.

SIRL - Shortage index for recreation.

RECL - Sum of recreation losses.

AVENB - Average annual net benefit.

AVVAR - Variance of annual net benefits.

DMR3S - Day of maximum reservoir level during third season.

FRS - Sum of reservoir sport fishery losses.

DAMIR - Day minimum reservoir level.

RLVA - Reservoir level. Used to determine reservoir level at end of water year.

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*       0175BA-2.DYN.RESULT.45.55.0.0
RUN     0175BA
NOTE
NOTE
NOTE    **********************************************************************
NOTE
NOTE                     SACRAMENTO STATE COLLEGE
NOTE                  PROJECT -- KERRI         PROGRAMMER -- HINRICHS
NOTE               DYNAMO HYDROLOGIC SIMULATION AND ECONOMIC MODEL
NOTE
NOTE    **********************************************************************
NOTE    DATE 8/6/69
NOTE    50 YEARS   SECOND INCREMENT OF IRRIGATION IN ORIGINAL ORDER
NOTE    CALAPOOIA RIVER MODEL
NOTE    MAXIMUM NET BENEFITS
NOTE    CURN=-UND
NOTE    HOLLEY K(+) = KS/1.1,K(-) = KS/1.35
NOTE    ALBANY K(+) = KS/1.2, K(-) = KS/1.45
NOTE
NOTE    DAY COUNTER
NOTE
1L      DAY.K=DAY.J+(DT)(DAIN.JK-DAOT.JK)                                       DC1
6R      DAIN.KL=DAC                                                             DC2
C       DAC=1                                                                   DC3
41R     DAOT.KL=PULSE(364,364,364)                                              DC4
NOTE
NOTE    SEASON COUNTER
NOTE
1L      SEA.K=SEA.J+(DT)(SEI.JK-SAO.JK)                                         SK1
6R      SEI.KL=SIC                                                              SK2
C       SIC=1                                                                   SK3
41R     SAO.KL=PULSE(91,91,91)                                                  SK4
NOTE
NOTE    YEARS COUNTER
NOTE
1L      YEARS.K=YEARS.J+(DT)(YRSIN.JK+0)                                        YC1
41R     YRSIN.KL=PULSE(1,364,364)                                               YC2
NOTE
NOTE    UPSTREAM HYDROLOGY
NOTE    RESERVOIR IN AT HOLLEY
NOTE
12R     RIN.KL=(FRIN1.K)(86400)                                                 UH1
28A     FRIN1.K=(1)EXP(LGRIN.K)                                                 UH2
7A      LGRIN.K=MRIN1.K+KR.K                                                    UH3
12A     KR.K=(KR1.K)(SRIN1.K)                                                   UH4
51A     KR1.K=CLIP(KR2.K,KR3.K,KRIN.K,0)                                        UH5
20A     KR2.K=KRIN.K/1.1                                                        UH6
20A     KR3.K=KRIN.K/1.35                                                       UH7
51A     MRIN1.K=CLIP(ARM.K,ARMX.K,91,DAY.K)                                     UH8
51A     ARMX.K=CLIP(BRM.K,BRMX.K,182,DAY.K)                                     UH9
51A     BRMX.K=CLIP(CRM.K,DRM.K,273,DAY.K)                                      UH10
58A     ARM.K=TABHL(ARMT,SEA.K,1,91,1)                                          UH11
58A     BRM.K=TABHL(BRMT,SEA.K,1,91,1)                                          UH12
58A     CRM.K=TABHL(CRMT,SEA.K,1,91,1)                                          UH13
58A     DRM.K=TABHL(DRMT,SEA.K,1,91,1)                                          UH14
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C      ARMT*=3.816/3.755/3.716/3.757/3.793/3.803/3.854/3.913/4.023/4.170/   UH15
X1     4.554/5.049/4.526/4.334/4.197/4.162/4.131/4.233/4.290/4.444/4.987/   UH16
X2     5.883/5.501/5.229/5.038/4.865/4.801/4.677/4.740/4.860/4.889/5.065/   UH17
X3     5.083/5.009/4.999/4.949/4.938/4.914/4.971/5.038/5.212/5.383/5.566/   UH18
X4     5.916/6.491/6.249/6.051/5.878/5.650/5.579/5.672/6.159/6.952/7.492/   UH19
X5     7.181/6.716/6.488/5.910/5.927/6.203/6.220/6.296/6.318/6.218/6.126/   UH20
X6     6.042/6.054/6.063/6.094/6.298/6.982/6.701/6.504/6.313/6.204/6.088/   UH21
X7     6.011/6.022/6.039/6.141/6.416/7.022/7.710/7.413/7.078/6.807/6.656/   UH22
X8     6.476/6.357/6.284/6.349                                              UH23
C      BRMT*=6.363/6.217/6.162/6.145/6.094/6.045/6.091/6.404/6.947/6.700/   UH24
X1     6.541/6.352/6.167/6.047/5.992/5.983/6.131/6.379/6.925/7.452/7.172/   UH25
X2     6.907/6.716/6.584/6.399/6.263/6.136/6.082/6.155/6.133/6.383/6.480/   UH26
X3     6.380/6.251/6.172/6.270/6.454/7.163/7.773/7.466/7.159/6.977/6.775/   UH27
X4     6.589/6.356/6.311/6.297/6.521/6.922/6.769/6.544/6.364/6.278/6.176/   UH28
X5     6.114/6.062/6.026/6.017/6.218/6.240/6.177/6.131/6.345/6.578/6.505/   UH29
X6     6.416/6.285/6.207/6.148/6.092/6.044/6.028/6.053/6.129/6.358/6.724/   UH30
X7     7.271/7.083/6.894/6.761/6.634/6.496/6.397/6.265/6.190/6.205/6.182/   UH31
X8     6.249/6.377/6.594/6.542                                              UH32
C      CRMT*=6.433/6.339/6.235/6.277/6.354/6.620/6.654/6.690/6.555/6.446/   UH33
X1     6.374/6.260/6.151/6.079/6.045/6.065/6.223/6.437/6.350/6.249/6.121/   UH34
X2     5.990/5.886/5.838/5.843/5.856/5.899/5.972/5.985/6.044/5.959/5.896/   UH35
X3     5.903/5.984/6.228/6.496/6.304/6.170/6.075/5.970/5.898/5.821/5.792/   UH36
X4     5.844/5.961/5.865/5.769/5.727/5.662/5.589/5.555/5.507/5.457/5.423/   UH37
X5     5.395/5.374/5.349/5.361/5.420/5.471/5.460/5.403/5.328/5.314/5.252/   UH38
X6     5.221/5.230/5.421/5.752/5.565/5.423/5.323/5.231/5.140/5.056/4.986/   UH39
X7     4.931/4.903/5.026/5.270/5.119/5.023/4.953/4.892/4.843/4.779/4.734/   UH40
X8     4.711/4.811/4.848/4.762                                              UH41
C      DRMT*=4.716/4.652/4.615/4.577/4.553/4.529/4.489/4.473/4.439/4.408/   UH42
X1     4.368/4.325/4.309/4.290/4.255/4.238/4.191/4.167/4.134/4.111/4.099/   UH43
X2     4.068/4.042/4.021/4.020/4.035/4.040/3.976/3.937/3.917/3.900/3.892/   UH44
X3     3.834/3.901/3.856/3.866/3.859/3.835/3.810/3.773/3.736/3.720/3.702/   UH45
X4     3.682/3.675/3.679/3.639/3.626/3.607/3.589/3.599/3.622/3.632/3.675/   UH46
X5     3.648/3.700/3.659/3.636/3.656/3.642/3.597/3.649/3.709/3.623/3.600/   UH47
X6     3.671/3.630/3.593/3.569/3.542/3.545/3.605/3.596/3.628/3.623/3.737/   UH48
X7     3.873/3.846/3.769/3.677/3.722/3.720/3.655/3.684/3.612/3.591/3.666/   UH49
X8     3.749/3.722/3.695/3.667                                              UH50
51A    SMIN1.K=CLIP(ARS.K,ARSX.K,91,DAY.K)                                  UH51
51A    ARSX.K=CLIP(BRS.K,BRSX.K,182,DAY.K)                                  UH52
51A    BRSX.K=CLIP(CRS.K,DRS.K,273,DAY.K)                                   UH53
58A    ARS.K=TABHL(ARST,SEA.K,1,91,1)                                       UH54
58A    BRS.K=TABHL(BRST,SEA.K,1,91,1)                                       UH55
58A    CRS.K=TABHL(CRST,SEA.K,1,91,1)                                       UH56
58A    DRS.K=TABHL(DRST,SEA.K,1,91,1)                                       UH57
C      ARST*=.660/.595/.500/.540/.550/.554/.595/.674/.814/.891/1.009/1.08   UH58
X1     4/.974/.902/.850/.901/.921/1.138/1.236/1.327/1.326/1.271/1.209/1.1   UH59
X2     45/1.093/1.057/1.089/1.173/1.225/1.328/1.090/1.183/1.156/1.072/0.9   UH60
X3     53/.884/.840/.831/.845/.882/.902/.921/.932/1.067/1.039/0.959/0.978   UH61
X4     /.991/.915/.961/1.001/1.045/0.959/1.013/0.984/1.015/.951/1.037/.91   UH62
X5     1/1.035/1.157/1.108/.960/.857/.765/.733/.719/.724/.811/.921/.763/.   UH63
X6     763/.714/.667/.645/.629/.636/.736/.809/.899/1.003/1.127/1.070/.977   UH64
X7     /.863/.746/.754/.699/.676/.570/.816                                  UH65
C      BRST*=.854/.756/.711/.742/.695/.690/.712/.772/.907/.838/.770/.673/   UH66
X1     .600/.570/.575/.607/.740/.842/.917/.902/.781/.742/.660/.609/.555/.   UH67
X2     518/.466/.532/.730/.810/.764/.779/.657/.562/.539/.551/.736/.763/.7   UH68
X3     26/.617/.537/.495/.497/.482/.479/.455/.536/.596/.750/.664/.615/.59   UH69
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X4      8/.587/.570/.497/.467/.446/.570/.662/.619/.633/.563/.572/.608/.560   UH70
X5      /.554/.470/.471/.457/.451/.447/.455/.514/.550/.636/.797/.622/.609/   UH71
X6      .608/.584/.544/.544/.522/.487/.499/.470/.480/.564/.650/.720/.684     UH72
C       CRST*=.629/.567/.509/.474/.495/.518/.509/.475/.463/.442/.440/.422/   UH73
X1      .412/.406/.426/.423/.461/.610/.582/.527/.475/.469/.474/.439/.432/.   UH74
X2      439/.423/.431/.435/.546/.488/.445/.470/.513/.656/.763/.656/.577/.5   UH75
X3      42/.523/.521/.505/.488/.561/.600/.588/.570/.549/.535/.511/.504/.49   UH76
X4      2/.479/.463/.441/.428/.427/.497/.534/.536/.463/.398/.375/.365/.374   UH77
X5      /.384/.428/.576/.667/.597/.535/.485/.439/.408/.389/.378/.371/.378/   UH78
X6      .457/.546/.459/.407/.377/.358/.338/.315/.302/.304/.556/.551/.468     UH79
C       DRST*=.440/.396/.366/.329/.318/.324/.339/.330/.336/.361/.331/.316/   UH80
X1      .298/.306/.317/.324/.288/.270/.265/.260/.264/.252/.243/.238/.263/.   UH81
X2      325/.430/.326/.285/.275/.277/.285/.278/.289/.298/.274/.300/.308/.2   UH82
X3      88/.261/.239/.227/.219/.222/.218/.231/.217/.221/.220/.237/.262/.31   UH83
X4      1/.340/.415/.335/.382/.365/.310/.332/.351/.272/.360/.569/.403/.381   UH84
X5      /.450/.444/.369/.347/.312/.293/.391/.448/.472/.443/.591/.719/.577/   UH85
X6      .498/.417/.603/.601/.500/.555/.489/.437/.611/.717/.607/.572/.484     UH86
20A     GRIN2.K=GRIN1.K/6                                                    UH87
51A     GRIN1.K=CLIP(ARG.K,ARGX.K,91,DAY.K)                                  UH88
51A     ARGX.K=CLIP(BRG.K,BRGX.K,182,DAY.K)                                  UH89
51A     BRGX,K=CLIP(CRG.K,DRG.K,273,DAY.K)                                   UH90
58A     ARG.K=TABHL(ARGT,SEA.K,1,91,1)                                       UH91
58A     BRG.K=TABHL(BRGT,SEA.K,1,91,1)                                       UH92
58A     CRG.K=TABHL(CRGT,SEA.K,1,91,1)                                       UH93
58A     DRG.K=TABHL(DRGT,SEA.K,1,91,1)                                       UH94
C       ARGT*=1.622/1.352/.917/.523/.468/.527/.309/.335/.461/.556/.309/-.2   UH95
X1      67/.323/.435/.432/.676/.548/1.271/1.171/.960/.346/-.485/-.513/-.45   UH96
X2      9/-.337/-.270/.022/1.019/1.241/.828/.611/.410/.578/.457/.137/.072/   UH97
X3      -.128/-.151/-.064/-.158/-.508/-.206/-.166/-.343/-.427/-.669/-.797/   UH98
X4      -.703/-.633/-.646/-.81/-1.228/-.399/-1.332/-1.357/-2.178/-2.128/-1   UH99
X5      .214/-1.312/-1.071/-.668/-.450/.174/.027/.050/.202/.410/.298/.564/   UH100
X6      .373/-.133/-.446/-.445/-.292/-.294/-.245/-.064/.295/.443/.284/.135   UH101
X7      /-.476/-.219/-.169/-.053/-.158/.203/.111/-.148/-.248/.458            UH102
C       BRGT*=1.154/.671/.390/.354/.302/.483/.551/.107/-.458/-.448/-.320/-   UH103
X1      .232/-.097/.037/.334/.408/.293/.077/.086/-.093/-.210/-.311/-.406/-   UH104
X2      .651/-.543/-.396/-.470/-.062/.611/.537/.233/.065/-.227/-.325/-.189   UH105
X3      /-.449/-.028/-.517/-.680/-.826/-.792/-.662/-.077/-.025/.141/.484/.   UH106
X4      408/-.283/-.323/-.269/-.217/-.086/-.079/-.055/.153/.332/-.104/.489   UH107
X5      /.280/.118/.113/.207/-.612/-.393/-.493/-.387/-.896/-.752/-.513/-.5   UH108
X6      03/-.418/-.362/-.246/-.424/-.667/-.377/-.446/-.282/-.378/-.490/-.5   UH109
X7      28/-.263/-.449/-.250/.034/.109/-.181/-.191/.349/-.526/-.617          UH110
C       CRGT*=-.487/-.599/-.754/-.573/-.690/-.750/-.607/-.890/-1.311/-1.13   UH111
X1      9/-.986/-1.261/-.975/-.724/-.671/-.738/-.775/-.423/-.473/-.569/-.5   UH112
X2      30/-.046/-.010/.108/.033/-.318/-.718/-1.000/-.924/.227/-.456/.079/   UH113
X3      .476/.090/.109/.244/-.026/-.206/-.414/-.306/-.170/-.261/-.574/-.42   UH114
X4      1/-.417/-.328/-.336/-.297/-.251/-.254/-.239/-.256/-.238/-.205/-.19   UH115
X5      8/-.288/-.196/.341/.396/.050/-.100/.289/.399/.292/.479/.418/.421/.   UH116
X6      289/.223/.153/.147/.028/-.092/-.121/-.089/-.020/.124/.215/.145/.00   UH117
X7      4/-.241/-.266/-.332/-.451/-.418/-.420/-.174/-.239/2.410/1.562/.966   UH118
X8                                                                           UH119
C       DRGT*=.598/.470/.384/.366/.230/-.073/.106/-.166/.223/.754/.436/.26   UH120
X1      1/-.066/.061/.192/.412/.160/.081/.047/.066/.295/.093/.121/.138/.28   UH121
X2      4/1.070/2.400/1.173/.587/.289/.309/.495/.041/.163/.310/-.014/.336/   UH122
X3      .900/.454/.165/-.013/-.122/-.084/-.070/-.039/.110/-.040/.021/-.003   UH123
X4      /.004/.608/.970/.870/1.221/.747/.966/1.254/.636/.879/1.367/.684/1.   UH124
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X5    311/3.047/2.311/1.818/1.331/2.009/1.413/1.528/.898/1.011/1.542/1.7  UH125
X6    76/1.988/1.595/1.964/1.376/.885/.775/.933/2.041/1.777/1.471/1.356/  UH126
X7    1.565/1.580/2.350/1.995/1.675/1.462/1.266                           UH127
7A    GRIN3.K=XRIN.K-GRIN2.K                                              UH128
14A   GRIN4.K=1+(GRIN2.K)(GRIN3.K)                                        UH129
13A   GRIN5.K=(GRIN4.K)(GRIN4.K)(GRIN4.K)                                 UH130
42A   GRIN6.K=1/((3)(GRIN2.K))                                            UH131
18A   KRN.K=(GRIN6.K)(GRIN5.K-1)                                          UH132
2 A   PKRN.K=-2/GRIN1.K                                                   UH133
49A   KRIN.K=SWITCH(XRIN.K,KRN1.K,GRIN1.K)                                UH134
7A    KRN2.K=KRN.K-PKRN.K                                                 UH135
51A   KRN3.K=CLIP(KRN.K,PKRN.K,KRN2.K,0)                                  UH136
51A   KRN4.K=CLIP(KRN.K,PKRN.K,-KRN2.K,0)                                 UH137
51A   KRN1.K=CLIP(KRN3.K,KRN4.K,GRIN1.K,0)                                UH138
15A   XRIN.K=(B2RIN.K)(YRIN.K)+(DRN2.K)(NDST1.K)                          UH139
7A    DRN1.K=1-DRIN.K                                                     UH140
30A   DRN2.K=(1)SQRT(DRN1.K)                                              UH141
51A   B2RIN.K=CLIP(ARB.K,ARBX.K,91,DAY.K)                                 UH142
51A   ARBX.K=CLIP(BRB.K,BRBX.K,182,DAY.K)                                 UH143
51A   BRBX.K=CLIP(CRB.K,DRB.K,273,DAY.K)                                  UH144
58A   ARB.K=TABHL(ARBT,SEA.K,1,91,1)                                      UH145
58A   BRB.K=TABHL(BRBT,SEA.K,1,91,1)                                      UH146
58A   CRB.K=TABHL(CRBT,SEA.K,1,91,1)                                      UH147
58A   DRB.K=TABHL(DRBT,SEA.K,1,91,1)                                      UH148
C     ARBT*=.722/.977/.964/.934/.952/.982/.957/.960/.965/.977/.934/.882/  UH149
X1    .864/.984/.989/.977/.991/.936/.992/.977/.816/.824/.979/.991/.997/.  UH150
X2    993/.970/.988/.936/.960/.936/.924/.972/.961/.898/.985/.977/.995/.9  UH151
X3    82/.988/.921/.933/.954/.887/.900/.965/.967/.979/.935/.925/.951/.88  UH152
X4    3/.765/.617/.930/.801/.820/.789/.863/.661/.964/.964/.959/.971/.989  UH153
X5    /.984/.876/.970/.988/.944/.918/.974/.951/.970/.989/.982/.978/.935/  UH154
X6    .990/.941/.909/.827/.856/.953/.959/.992/.993/.994/.933/.965/.864    UH155
C     BRBT*=.942/.874/.960/.860/.985/.973/.957/.840/.775/.978/.986/.940/  UH156
X1    .944/.980/.946/.974/.906/.855/.823/.927/.962/.967/.988/.984/.963/.  UH157
X2    978/.978/.788/.920/.952/.825/.851/.908/.966/.941/.817/.867/.448/.7  UH158
X3    88/.955/.897/.914/.961/.951/.896/.925/.804/.849/.556/.982/.954/.96  UH159
X4    6/.990/.988/.978/.979/.910/.800/.878/.906/.974/.913/.827/.902/.939  UH160
X5    /.989/.944/.990/.958/.993/.958/.957/.961/.940/.887/.912/.804/.970/  UH161
X6    .958/.960/.977/.942/.946/.912/.937/.851/.927/.876/.927/.831/.972    UH162
C     CRBT*=.974/.991/.974/.895/.905/.850/.962/.967/.977/.967/.984/.962/  UH163
X1    .958/.988/.985/.943/.906/.906/.991/.987/.976/.948/.967/.986/.954/.  UH164
X2    965/.959/.923/.915/.779/.939/.921/.971/.935/.915/.912/.963/.973/.9  UH165
X3    92/.966/.995/.980/.958/.959/.932/.939/.994/.990/.996/.991/.998/.99  UH166
X4    7/.997/.997/.991/.988/.984/.949/.948/.846/.914/.958/.957/.911/.877  UH167
X5    /.982/.969/.841/.860/.983/.989/.993/.990/.990/.992/.995/.992/.958/  UH168
X6    .821/.877/.978/.972/.992/.994/.998/.988/.990/.965/.795/.900/.908    UH169
C     DRBT*=.987/.997/.993/.989/.985/.988/.976/.921/.965/.993/.997/.995/  UH170
X1    .974/.974/.973/.992/.992/.993/.996/.997/.969/.993/.992/.995/.963/.  UH171
X2    974/.918/.918/.991/.996/.991/.989/.952/.939/.960/.967/.944/.979/.9  UH172
X3    84/.990/.991/.990/.992/.993/.959/.988/.971/.991/.993/.984/.981/.88  UH173
X4    3/.921/.916/.971/.819/.990/.983/.844/.921/.859/.680/.806/.929/.937  UH174
X5    /.688/.864/.889/.962/.928/.907/.820/.969/.929/.801/.784/.842/.919/  UH175
X6    .932/.973/.839/.855/.987/.872/.986/.951/.875/.931/.895/.951/.802    UH176
43A   AR01.K=SAMPLE(UND01.K,1)                                            UH177
33A   UND01.K=(1)NOISE                                                    UH178
43A   AR02.K=SAMPLE(UND02.K,1)                                            UH179
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33A     UND02.K=(1)NOISE                                                     UH180
43A     AR03.K=SAMPLE(UND03.K,1)                                             UH181
33A     UND03.K=(1)NOISE                                                     UH182
43A     AR04.K=SAMPLE(UND04.K,1)                                             UH183
33A     UND04.K=(1)NOISE                                                     UH184
43A     AR05.K=SAMPLE(UND05.K,1)                                             UH185
33A     UND05.K=(1)NOISE                                                     UH186
43A     AR06.K=SAMPLE(UND06.K,1)                                             UH187
33A     UND06.K=(1)NOISE                                                     UH188
43A     AR07.K=SAMPLE(UND07.K,1)                                             UH189
33A     UND07.K=(1)NOISE                                                     UH190
43A     AR08.K=SAMPLE(UND08.K,1)                                             UH191
33A     UND08.K=(1)NOISE                                                     UH192
43A     AR09.K=SAMPLE(UND09.K,1)                                             UH193
33A     UND09.K=(1)NOISE                                                     UH194
43A     AR010.K=SAMPLE(UND10.K,1)                                            UH195
33A     UND10.K=(1)NOISE                                                     UH196
43A     AR011.K=SAMPLE(UND11.K,1)                                            UH197
33A     UND11.K=(1)NOISE                                                     UH198
43A     AR012.K=SAMPLE(UND12.K,1)                                            UH199
33A     UND12.K=(1)NOISE                                                     UH200
10A     SMUD1.K=AR01.K+AR02.K+AR03.K+AR04.K+AR05.K+AR06.K                    UH201
10A     SMUD2.K=AR07.K+AR08.K+AR09.K+AR010.K+AR011.K+AR012.K                 UH202
7A      NDST1.K=SMUD1.K+SMUD2.K                                              UH203
51A     DRIN.K=CLIP(ARD.K,ARDX.K,91,DAY.K)                                   UH204
51A     ARDX.K=CLIP(BRD.K,BRDX.K,182,DAY.K)                                  UH205
51A     BRDX.K=CLIP(CRD.K,DRD.K,273,DAY.K)                                   UH206
58A     ARD.K=TABHL(ARDT,SEA.K,1,91,1)                                       UH207
58A     BRD.K=TABHL(BRDT,SEA.K,1,91,1)                                       UH208
58A     CRD.K=TABHL(CRDT,SEA.K,1,91,1)                                       UH209
58A     DRD.K=TABHL(DRDT,SEA.K,1,91,1)                                       UH210
C       ARDT*=.521/.955/.928/.872/.912/.964/.916/.961/.930/.954/.872/.778/   UH211
X1      .746/.968/.979/.954/.962/.973/.984/.954/.666/.679/.959/.982/.993/.   UH212
X2      986/.941/.973/.877/.922/.915/.854/.944/.924/.807/.970/.955/.991/.9   UH213
X3      64/.971/.848/.870/.911/.788/.810/.931/.935/.959/.874/.858/.905/.78   UH214
X4      0/.585/.381/.865/.642/.672/.503/.744/.437/.929/.929/.920/.944/.977   UH215
X5      /.967/.767/.941/.975/.892/.843/.949/.962/.941/.978/.964/.957/.874/   UH216
X6      .981/.886/.826/.685/.732/.967/.939/.984/.986/.988/.967/.932/.747     UH217
C       BRDT*=.888/.764/.961/.739/.959/.947/.916/.706/.601/.956/.973/.884/   UH218
X1      .892/.961/.894/.949/.821/.731/.677/.858/.964/.935/.977/.968/.928/.   UH219
X2      957/.956/.622/.846/.907/.681/.776/.624/.934/.866/.668/.751/.201/.5   UH220
X3      90/.912/.805/.835/.924/.905/.803/.855/.646/.720/.309/.963/.910/.93   UH221
X4      4/.981/.977/.953/.959/.828/.750/.460/.820/.949/.833/.864/.813/.863   UH222
X5      /.979/.892/.980/.976/.965/.917/.975/.923/.864/.787/.831/.846/.942/   UH223
X6      .917/.922/.955/.867/.895/.831/.879/.724/.859/.767/.859/.691/.945     UH224
C       CRDT*=.948/.982/.949/.801/.818/.430/.925/.936/.955/.935/.969/.925/   UH225
X1      .914/.977/.971/.890/.821/.821/.983/.974/.953/.899/.934/.973/.910/.   UH226
X2      931/.920/.852/.836/.607/.881/.848/.943/.874/.838/.831/.927/.948/.9   UH227
X3      84/.932/.991/.960/.914/.919/.865/.975/.985/.980/.992/.983/.996/.99   UH228
X4      4/.994/.993/.982/.976/.969/.900/.899/.715/.835/.918/.916/.829/.770   UH229
X5      /.963/.939/.707/.739/.965/.978/.988/.980/.979/.985/.990/.984/.977/   UH230
X6      .674/.769/.958/.945/.964/.989/.992/.976/.979/.932/.632/.811/.825     UH231
C       DRDT*=.974/.994/.987/.978/.971/.938/.953/.847/.931/.987/.994/.990/   UH232
X1      .949/.949/.947/.984/.984/.987/.992/.993/.940/.985/.984/.991/.928/.   UH233
X2      949/.843/.842/.983/.991/.981/.978/.919/.863/.922/.936/.891/.959/.9   UH234
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X3    68/.981/.982/.981/.985/.957/.920/.933/.943/.982/.987/.968/.963/.78  UH235
X4    0/.848/.839/.943/.671/.979/.928/.712/.848/.738/.462/.649/.863/.879  UH236
X5    /.446/.746/.790/.925/.862/.822/.672/.939/.863/.641/.615/.709/.845/  UH237
X6    .868/.947/.704/.732/.973/.760/.972/.904/.766/.867/.800/.905/.644    UH238
6R    YRIN1.KL=XRIN.K                                                     UH239
6A    YRIN.K=YRIN1.JK                                                     UH240
6R    NBST1.KL=NDST1.K                                                    UH241
6A    NAST1.K=NBST1.JK                                                    UH242
NOTE
NOTE  DOWNSTREAM HYDROLOGY
NOTE  CHANNEL IN AT ALBANY
NOTE
12R   CIN.KL=(FCIN2.K)(86400)                                             DH1
51A   FCIN2.K=CLIP(FCIN1.K,FRIN3.K,FCIN1.K,FRIN3.K)                       DH2
28A   FCIN1.K=(1)EXP(LGCIN.K)                                             DH3
7A    LGCIN.K=MCIN1.K+KC.K                                                DH4
12A   KC.K=(KC1.K)(SCIN1.K)                                               DH5
51A   KC1.K=CLIP(KC2.K,KC3.K,KCIN.K,0)                                    DH6
20A   KC2.K=KCIN.K/1.2                                                    DH7
20A   KC3.K=KCIN.K/1.45                                                   DH8
51A   MCIN1.K=CLIP(ACM.K,ACMX.K,91,DAY.K)                                 DH9
51A   ACMX.K=CLIP(BCM.K,BCMX.K,182,DAY.K)                                 DH10
51A   BCMX.K=CLIP(CCM.K,DCM.K,273,DAY.K)                                  DH11
58A   ACM.K=TABHL(ACMT,SEA.K,1,91,1)                                      DH12
58A   BCM.K=TABHL(BCMT,SEA.K,1,91,1)                                      DH13
58A   CCM.K=TABHL(CCMT,SEA.K,1,91,1)                                      DH14
58A   DCM.K=TABHL(DCMT,SEA.K,1,91,1)                                      DH15
C     ACMT*=3.945/3.914/3.931/3.945/4.000/4.035/4.063/4.077/4.134/4.198/  DH16
X1    4.314/4.656/4.952/4.683/4.504/4.434/4.465/4.433/4.491/4.572/4.836/  DH17
X2    5.390/6.005/5.727/5.423/5.198/5.052/4.984/5.032/5.069/5.294/5.189/  DH18
X3    5.257/5.301/5.262/5.229/5.257/5.221/5.300/5.266/5.334/5.504/5.677/  DH19
X4    5.983/6.247/6.557/6.856/6.542/6.205/6.175/5.659/6.118/6.339/7.189/  DH20
X5    8.119/7.796/7.557/7.108/6.852/6.691/6.786/6.820/6.755/6.719/6.670/  DH21
X6    6.640/6.634/6.547/6.644/6.792/7.092/7.606/7.332/7.130/6.961/6.796/  DH22
X7    6.665/6.580/6.624/6.715/6.942/7.339/7.995/8.463/8.244/7.671/7.563/  DH23
X8    7.368/7.204/7.090/7.122                                             DH24
C     BCMT*=7.050/6.943/6.855/6.742/6.655/6.774/6.955/7.221/7.523/7.757/  DH25
X1    7.571/7.332/7.095/6.936/6.821/6.772/6.911/7.199/7.660/8.152/8.412/  DH26
X2    8.062/7.758/7.542/7.387/7.169/7.019/6.896/6.883/6.853/7.179/7.299/  DH27
X3    7.064/6.918/6.899/6.986/7.209/7.605/8.152/8.599/8.396/8.062/7.811/  DH28
X4    7.539/7.354/7.061/7.051/7.065/7.357/7.650/7.473/7.257/7.118/6.912/  DH29
X5    6.735/6.610/6.582/6.754/6.945/6.921/6.813/6.777/6.842/7.018/7.364/  DH30
X6    7.235/7.066/6.856/6.813/6.636/6.636/6.629/6.630/6.729/6.985/7.284/  DH31
X7    7.715/8.077/7.876/7.627/7.373/7.202/7.009/6.831/6.735/6.661/6.631/  DH32
X8    6.706/6.992/7.292/7.096                                             DH33
C     CCMT*=7.005/6.849/6.723/6.649/6.730/6.677/7.115/7.318/7.156/6.960/  DH34
X1    6.848/6.755/6.626/6.512/6.429/6.349/6.480/6.687/6.925/6.794/6.649/  DH35
X2    6.460/6.316/6.225/6.192/6.164/6.213/6.264/6.346/6.312/6.254/6.262/  DH36
X3    6.244/6.249/6.394/6.685/6.935/6.746/6.507/6.389/6.296/6.194/6.105/  DH37
X4    6.121/6.214/6.400/6.278/6.137/6.057/5.999/5.932/5.870/5.809/5.759/  DH38
X5    5.730/5.702/5.659/5.622/5.626/5.706/5.783/5.726/5.667/5.635/5.581/  DH39
X6    5.565/5.545/5.576/5.726/5.965/5.836/5.718/5.625/5.536/5.469/5.404/  DH40
X7    5.356/5.308/5.304/5.369/5.575/5.458/5.377/5.315/5.269/5.226/5.203/  DH41
X8    5.179/5.258/5.285/5.178                                             DH42
C     DCMT*=5.128/5.101/5.066/5.025/4.995/4.986/4.959/4.939/4.925/4.885/  DH43
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X1      4.851/4.826/4.804/4.795/4.783/4.755/4.727/4.692/4.655/4.624/4.604/   DH44
X2      4.580/4.558/4.544/4.538/4.549/4.553/4.544/4.519/4.493/4.412/4.404/   DH45
X3      4.394/4.405/4.390/4.362/4.364/4.379/4.355/4.335/4.310/4.297/4.290/   DH46
X4      4.272/4.259/4.251/4.234/4.213/4.195/4.170/4.151/4.147/4.158/4.141/   DH47
X5      4.118/4.087/4.030/3.980/3.944/3.898/3.828/3.789/3.793/3.800/3.842/   DH48
X6      3.796/3.737/3.800/3.798/3.779/3.770/3.794/3.788/3.774/3.786/3.876/   DH49
X7      3.908/3.927/4.009/3.984/3.919/3.883/3.894/3.940/3.886/3.853/3.800/   DH50
X8      3.932/3.945/3.945/3.913                                              DH51
51A     SCIN1.K=CLIP(ACS.K,ACSX.K,91,DAY.K)                                  DH52
51A     ACSX.K=CLIP(BCS.K,BCSX.K,182,DAY.K)                                  DH53
51A     BCSX.K=CLIP(CCS.K,DCS.K,273,DAY.K)                                   DH54
58A     ACS.K=TABHL(ACST,SEA.K,1,91,1)                                       DH55
58A     BCS.K=TABHL(BCST,SEA.K,1,91,1)                                       DH56
58A     CCS.K=TABHL(CCST,SEA.K,1,91,1)                                       DH57
58A     DCS.K=TABHL(DCST,SEA.K,1,91,1)                                       DH58
C       ACST*=.490/.475/.512/.507/.486/.572/.585/.624/.666/.735/.830/1.022   DH59
X1      /1.078/.991/.909/.832/.891/.965/1.108/1.209/1.265/1.366/1.334/1.29   DH60
X2      3/1.203/1.152/1.126/1.128/1.196/1.371/1.352/1.474/1.441/1.266/1.19   DH61
X3      1/1.171/1.082/1.041/1.007/1.010/.969/.956/1.109/1.043/1.013/1.073/   DH62
X4      1.148/1.128/1.099/1.021/1.039/1.141/1.168/1.405/1.197/1.293/1.347/   DH63
X5      1.205/1.190/1.309/1.339/1.365/1.397/1.249/1.098/1.015/.939/.926/.9   DH64
X6      14/.931/.964/.789/.774/.761/.740/.741/.713/.745/.803/.948/1.040/1.   DH65
X7      074/1.035/1.053/1.007/.961/.874/.875/.897/.852/.824                  DH66
C       BCST*=.921/.984/.871/.791/.655/.750/.627/.822/.924/.960/.937/.816/   DH67
X1      .731/.692/.662/.722/.837/.930/.891/.947/.942/.905/.830/.799/.757/.   DH68
X2      723/.712/.719/.770/.840/.885/.823/.869/.590/.494/.512/.556/.541/.6   DH69
X3      55/.761/.700/.609/.589/.608/.628/.661/.654/.570/.714/.807/.781/.70   DH70
X4      0/.668/.587/.535/.534/.534/.559/.613/.687/.621/.563/.600/.659/.672   DH71
X5      /.649/.657/.613/.603/.585/.579/.621/.648/.753/.759/.797/.878/.690/   DH72
X6      .675/.676/.677/.669/.652/.600/.567/.539/.571/.610/.805/.958/.874     DH73
C       CCST*=.780/.685/.599/.483/.492/.558/.640/.659/.658/.591/.564/.521/   DH74
X1      .481/.475/.509/.490/.592/.667/.751/.707/.652/.604/.544/.476/.452/.   DH75
X2      460/.474/.527/.535/.488/.487/.532/.528/.551/.734/.922/.950/.847/.6   DH76
X3      83/.618/.560/.557/.520/.572/.624/.639/.699/.617/.611/.602/.585/.54   DH77
X4      0/.535/.527/.521/.545/.533/.542/.501/.595/.505/.442/.405/.356/.379   DH78
X5      /.382/.409/.442/.538/.609/.550/.499/.447/.399/.356/.353/.337/.323/   DH79
X6      .334/.367/.453/.354/.346/.331/.314/.305/.297/.281/.463/.440/.472     DH80
C       DCST*=.390/.357/.325/.327/.303/.297/.306/.304/.311/.313/.309/.310/   DH81
X1      .302/.304/.319/.302/.294/.281/.273/.268/.262/.263/.253/.250/.272/.   DH82
X2      323/.391/.408/.365/.334/.287/.289/.287/.293/.289/.288/.298/.309/.2   DH83
X3      98/.287/.282/.276/.268/.264/.264/.270/.281/.267/.263/.259/.257/.26   DH84
X4      3/.304/.327/.330/.337/.319/.288/.281/.300/.250/.292/.300/.339/.453   DH85
X5      /.404/.329/.361/.370/.345/.340/.383/.362/.361/.473/.495/.593/.560/   DH86
X6      .556/.490/.442/.427/.549/.607/.527/.484/.452/.675/.612/.500/.490     DH87
20A     GCIN2.K=GCIN1.K/6                                                    DH88
51A     GCIN1.K=CLIP(ACG.K,ACGX.K,91,DAY.K)                                  DH89
51A     ACGX.K=CLIP(BCG.K,BCGX.K,182,DAY.K)                                  DH90
51A     BCGX.K=CLIP(CCG.K,DCG.K,273,DAY.K)                                   DH91
58A     ACG.K=TABHL(ACGT,SEA.K,1,91,1)                                       DH92
58A     BCG.K=TABHL(BCGT,SEA.K,1,91,1)                                       DH93
58A     CCG.K=TABHL(CCGT,SEA.K,1,91,1)                                       DH94
58A     DCG.K=TABHL(DCGT,SEA.K,1,91,1)                                       DH95
C       ACGT*=1.075/.766/.723/.525/.405/.275/.423/.507/.598/.662/.410/.430   DH96
X1      /.140/.178/.233/.220/.536/.797/1.293/1.409/.974/.402/-.142/-.075/-   DH97
X2      .060/-.051/.053/.414/.869/1.567/1.165/.909/.661/.677/.748/.342/.45   DH98
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X3     7/-.107/-.230/-.257/-.202/-.604/-1.013/-.200/.174/-.410/-.595/-.62  DH99
X4     7/-.724/-.556/-.513/-.552/-.456/-.595/-1.173/-1.837/-1.439/-1.494/  DH100
X5     -1.126/-1.044/-.532/-.585/-.541/-.297/.078/.061/.099/.227/.346/.06  DH101
X6     3/-.075/-.088/-.268/-.343/-.389/-.497/-.367/-.049/.147/.229/.142/-  DH102
X7     .106/-.431/-.400/-.419/-.242/-.092/.208/.346/.416/.681              DH103
C      BCGT*=1.086/1.087/.644/.457/-.121/-.008/-.038/-.203/-.498/-.564/-.  DH104
X1     396/-.295/.038/.260/.574/.647/.566/.220/-.291/-.200/-.658/-.785/-.  DH105
X2     625/-.647/-.447/-.223/-.026/.162/.199/.591/.263/-.242/-.263/-.276/  DH106
X3     .063/.254/-.159/-.648/-.986/-.653/-1.290/-1.485/-.969/-.009/.323/.  DH107
X4     535/.547/.195/-.327/-.488/-.321/-.310/-.208/-.157/.121/.228/.452/.  DH108
X5     366/.593/.169/.199/.489/.283/-.156/-.508/-.455/-.519/-.719/-.605/-  DH109
X6     .106/.167/.493/.736/.727/.325/-.239/-.858/-.498/-.421/-.411/-.399/  DH110
X7     -.352/-.186/-.128/.122/-.230/-.152/.099/.308/.203/-.240             DH111
C      CCGT*=.056/.271/.308/.112/-.005/-.115/-.197/-.156/-.173/-.413/-.38  DH112
X1     3/-.444/-.659/-.416/.059/.520/.767/.210/-.269/-.288/-.277/-.048/-.  DH113
X2     091/-.026/-.043/-.123/-.166/.282/-.143/-.610/-.506/.239/.770/.609/  DH114
X3     .886/.627/.273/.149/.071/-.153/0.019/.018/-.095/.184/.432/.081/.08  DH115
X4     9/-.118/-.009/-.006/.053/-.106/-.040/.052/.116/.276/.291/.335/.053  DH116
X5     /.624/.451/.550/.506/.243/.378/.360/.326/.326/.051/.198/.109/.094/  DH117
X6     -.027/-.245/-.313/-.246/-.195/-.041/.025/-.019/-.100/-.351/-.373/-  DH118
X7     .366/-.337/-.315/-.197/-.201/2.132/1.346/1.721                      DH119
C      DCGT*=.857/.453/.250/.141/.105/-.006/.090/.067/.093/.227/.445/.378  DH120
X1     /.152/-.164/.035/.255/.525/.300/.260/.227/.235/.169/.309/.326/.220  DH121
X2     /.563/1.352/1.367/.935/.679/.057/.090/.079/.005/-.081/-.113/-.037/  DH122
X3     .15/.031/-.053/-.015/.065/.126/.111/.056/-.019/.214/.106/.061/.045/ DH123
X4     -.059/-.078/.252/.627/.752/1.403/1.416/.934/.495/.984/.019/.998/1.  DH124
X5     529/1.793/3.034/2.673/2.405/1.738/1.693/1.461/1.477/.880/.633/1.10  DH125
X6     2/1.947/1.561/2.046/1.652/1.037/1.147/1.231/1.471/2.091/1.370/1.32  DH126
X7     8/1.360/1.363/2.323/1.904/1.414/1.471                               DH127
7A     GCIN3.K=XCIN.K-GCIN2.K                                              DH128
14A    GCIN4.K=1+(GCIN2.K)(GCIN3.K)                                        DH129
13A    GCIN5.K=(GCIN4.K)(GCIN4.K)(GCIN4.K)                                 DH130
42A    GCIN6.K=1/((3)(GCIN2.K))                                            DH131
18A    KCN.K=(GCIN6.K)(GCIN5.K-1)                                          DH132
20A    PKCN.K=-2/GCIN1.K                                                   DH133
47A    KCIN.K=SWITCH(XCIN.K,KCN1.K,GCIN1.K)                                DH134
7A     KCN2.K=KCN.K-PKCN.K                                                 DH135
51A    KCN3.K=CLIP(KCN.K,PKCN.K,KCN2.K,0)                                  DH136
51A    KCN4.K=CLIP(KCN.K,PKCN.K,-KCN2.K,0)                                 DH137
51A    KCN1.K=CLIP(KCN3.K,KCN4.K,GCIN1.K,0)                                DH138
17A    XCIN.K=(1)(B2CIN.K)(YCIN.K)+(1)(B3CIN.K)(XRIN.K)+(1)(DCIN2.K)(NAST  DH139
X1     1.K)                                                                DH139
7A     DCIN3.K=1-DCIN1.K                                                   DH140
30A    DCIN2.K=(1)SQRT(DCIN3.K)                                            DH141
51A    B2CIN.K=CLIP(ACB2.K,ACB2X.K,91,DAY.K)                               DH142
51A    ACB2X.K=CLIP(BCB2.K,BCB2X.K,182,DAY.K)                              DH143
51A    BCB2X.K=CLIP(CCB2.K,DCB2.K,273,DAY.K)                               DH144
58A    ACB2.K=TABHL(ACB2T,SEA.K,1,91,1)                                    DH145
58A    BCB2.K=TABHL(BCB2T,SEA.K,1,91,1)                                    DH146
58A    CCB2.K=TABHL(CCB2T,SEA.K,1,91,1)                                    DH147
58A    DCB2.K=TABHL(DCB2T,SEA.K,1,91,1)                                    DH148
C      ACB2T*=.772/.406/.418/.708/.645/.363/.653/.870/.816/.707/.646/.691  DH149
X1     /.247/.606/.749/.630/.370/.662/.467/1.018/.782/.561/.162/.696/.733  DH150
X2     /.480/.842/.579/.394/.666/.184/.927/.822/.850/.835/.826/.564/.594/  DH151
X3     .715/.822/.849/.706/.621/.710/.903/.208/.994/.702/.812/.450/.940/.  DH152
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X4    849/.892/.669/.364/0.952/.588/.680/.967/.778/.230/.874/.697/.764/.   DH153
X5    591/.623/.873/.760/.903/.905/.764/.551/.984/.846/.759/.766/.872/.8   DH154
X6    56/.389/.903/.827/.586/.640/.435/.894/.821/.941/.576/.923/.743/.66   DH155
X7    2                                                                    DH156
C     BCB2T*=.559/.762/.895/.849/.724/.796/.634/.935/.528/.792/.976/.823   DH157
X1    /.774/.918/.918/.716/.826/.751/.532/.614/.703/.604/.681/.951/1.009   DH158
X2    /1.039/.945/.823/.538/.854/.162/.298/.823/.985/.902/.876/.742/.652   DH159
X3    /.591/.283/.937/.657/.894/.980/.907/.837/.852/.774/.471/.748/.973/   DH160
X4    1.065/.930/.757/.676/.633/.559/.656/.181/.363/.735/.662/.670/.868/   DH161
X5    .566/.921/.904/.694/.692/.291/.928/.849/.761/.996/.822/.832/.684/.   DH162
X6    568/.949/.842/.858/.747/.708/.784/.520/.795/.761/.628/.487/.748/.3   DH163
X7    38                                                                   DH164
C     CCB2T*=.716/.735/1.017/.695/.538/.598/.475/.518/.886/.790/.824/.89   DH165
X1    3/.835/.733/.952/.660/.743/.846/.780/.964/.901/.742/.499/.667/.906   DH166
X2    /.852/.501/.763/.600/.820/.743/.858/.922/.842/.540/.494/.345/.804/   DH167
X3    .783/.842/.773/.874/.893/.883/.507/.576/.941/.716/.773/.928/.975/.   DH168
X4    834/.870/.901/.969/.735/.952/.950/.713/.510/.235/.587/.766/.857/.8   DH169
X5    60/.856/.621/.825/.540/.140/.460/.789/1.065/.565/.834/.948/.923/1.   DH170
X6    134/.791/.622/.268/.601/.520/.996/1.094/1.017/.959/.734/.579/.380/   DH171
X7    -.203                                                                DH172
C     DCB2T*=.683/.962/.990/1.014/.908/.893/.867/.723/.951/.864/.906/1.0   DH173
X1    19/.942/.858/.851/.878/.991/1.038/1.033/1.040/1.017/1.004/.960/.99   DH174
X2    3/.798/.841/1.004/1.028/.942/.965/.738/.964/.961/.869/1.042/.866/.   DH175
X3    828/.980/.974/1.038/1.039/1.007/.992/.998/1.021/.960/.982/.996/.98   DH176
X4    7/.999/1.004/.913/.748/.830/.890/.871/.995/.980/.849/.953/1.016/.7   DH177
X5    96/.853/.839/.016/.897/.802/.723/.859/.602/.817/.384/.817/.825/.99   DH178
X6    2/.597/.864/.511/.632/.815/.810/.812/.529/.062/.940/.922/.884/.320   DH179
X7    /.288/.555/.232                                                      DH180
51A   B3CIN.K=CLIP(ACB3.K,ACB3X.K,91,DAY.K)                                DH181
51A   ACB3X.K=CLIP(BCB3.K,BCB3X.K,182,DAY.K)                               DH182
51A   BCB3X.K=CLIP(CCB3.K,DCB3.K,273,DAY.K)                                DH183
58A   ACB3.K=TABHL(ACB3T,SEA.K,1,91,1)                                     DH184
58A   BCB3.K=TABHL(BCB3T,SEA.K,1,91,1)                                     DH185
58A   CCB3.K=TABHL(CCB3T,SEA.K,1,91,1)                                     DH186
58A   DCB3.K=TABHL(DCB3T,SEA.K,1,91,1)                                     DH187
C     ACB3T*=.105/.606/.568/.268/.358/.630/.149/.124/.179/.298/.344/.302   DH188
X1    /.742/.322/.247/.363/.828/.317/.522/-.031/.220/.394/.833/.303/.268   DH189
X2    /.516/.361/.424/.615/.228/.833/.061/.399/.165/.175/.145/.476/.415/   DH190
X3    .293/.183/.132/.246/.297/.283/.083/.737/-.002/.251/.189/.545/.038/   DH191
X4    .139/.054/.287/.61/-.084/.407/.202/-.001/.233/.762/.339/.311/.245/   DH192
X5    .418/.362/.109/.263/.095/.087/.206/.454/-.003/.155/.235/.242/.307/   DH193
X6    .149/.595/.088/.135/.380/.298/.577/.100/.150/.055/.129/.065/.259/.   DH194
X7    306                                                                  DH195
C     BCB3T*=.450/.188/.111/.152/.281/.165/.343/-.001/.471/.166/.019/.18   DH196
X1    3/.189/.083/.054/.257/.108/.170/.448/.372/.299/.413/.298/.037/-.02   DH197
X2    7/-.068/.046/.182/.480/.359/.509/.700/.080/-.010/-.000/.052/.025/.   DH198
X3    316/.331/.691/-.004/.310/.045/-.023/.101/-.041/.166/.158/.486/.235   DH199
X4    /.001/-.132/.063/.253/.328/.351/.435/.237/.797/.593/.238/.309/.250   DH200
X5    /.098/.321/.094/.100/.325/.324/.701/.087/.143/.221/-.016/.154/.195   DH201
X6    /.317/.392/.037/.142/.379/.252/.284/.196/.181/.169/.211/.344/.444/   DH202
X7    .143/.884                                                            DH203
C     CCB3T*=.29/.253/-.025/.288/.493/.573/.555/.477/.117/.193/.177/.112   DH204
X1    /.164/.276/.028/.322/.247/.384/.178/.035/.384/.273/.518/.322/.077/   DH205
X2    .151/.494/.270/.393/.208/.271/.143/.079/.151/.474/.502/.660/.203/.   DH206
X3    220/.163/.228/.123/.112/.292/.184/.318/.064/.312/.237/.075/.018/.1   DH207
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X4    71/.129/.104/.030/.268/.048/.045/.282/.500/.760/.413/.236/.156/.13    DH208
X5    9/.357/.376/.199/.499/.858/.517/.205/-.073/.134/.170/.048/.080/-.1    DH209
X6    62/.221/.364/.751/.396/.469/-.015/-.105/-.026/.065/.295/.344/.679/    DH210
X7    1.050                                                                 DH211
C     DCB3T*=.327/.029/.002/-.024/.071/.101/.126/.209/.027/.146/.094/-.0    DH212
X1    28/.058/.151/.149/.122/-.006/-.054/-.047/-.056/-.028/-.013/.042/-.    DH213
X2    007/.222/.169/-.021/-.039/.058/.026/.180/.036/.030/.154/-.070/.145    DH214
X3    /.187/.016/.009/-.035/-.061/-.014/.008/.003/-.048/.043/.019/.002/.    DH215
X4    015/-.000/-.010/.100/.265/.134/.112/.139/-.013/.022/.173/.051/-.04    DH216
X5    3/.211/.026/.20[illegible]/.775/.092/.471/.273/.145/.429/.373/.392/.162/.147    DH217
X6    /-.057/.354/.210/.380/.332/.426/.164/.231/.465/.907/.056/.071/.276    DH218
X7    /.710/.719/.429/.766                                                  DH219
51A   DCIN1.K=CLIP(ACD.K,ACDX.K,91,DAY.K)                                   DH220
51A   ACDX.K=CLIP(BCD.K,BCDX.K,182,DAY.K)                                   DH221
51A   BCDX.K=CLIP(CCD.K,DCD.K,273,DAY.K)                                    DH222
55A   ACD.K=TABHL(ACDT,SEA.K,1,91,1)                                        DH223
55A   BCD.K=TABHL(BCDT,SEA.K,1,91,1)                                        DH224
55A   CCD.K=TABHL(CCDT,SEA.K,1,91,1)                                        DH225
55A   DCD.K=TABHL(DCDT,SEA.K,1,91,1)                                        DH226
C     ACDT*=.713/.842/.904/.894/.913/.951/.934/.965/.956/.933/.926/.879/    DH227
X1    .965/.963/.976/.982/.902/.955/.963/.977/.927/.886/.961/.962/.991/.    DH228
X2    981/.986/.979/.980/.781/.973/.964/.983/.987/.943/.900/.963/.973/.9    DH229
X3    82/.989/.938/.845/.763/.855/.939/.830/.983/.930/.972/.914/.950/.92    DH230
X4    5/.857/.780/.802/.809/.863/.706/.934/.963/.934/.975/.976/.986/.979    DH231
X5    /.948/.930/.900/.989/.910/.841/.870/.962/.956/.939/.964/.905/.973/    DH232
X6    .923/.932/.855/.880/.850/.953/.972/.921/.962/.934/.960/.952/.856      DH233
C     BCDT*=.939/.864/.970/.937/.923/.850/.873/.873/.851/.870/.961/.970/    DH234
X1    .871/.973/.925/.800/.842/.750/.763/.805/.930/.965/.925/.969/.969/.    DH235
X2    963/.960/.907/.570/.927/.865/.916/.801/.956/.813/.826/.572/.674/.7    DH236
X3    18/.851/.873/.829/.804/.927/.947/.865/.832/.717/.789/.903/.948/.93    DH237
X4    8/.955/.836/.894/.952/.920/.720/.920/.853/.904/.856/.762/.862/.638    DH238
X5    /.970/.969/.955/.900/.953/.971/.961/.924/.960/.861/.934/.909/.832/    DH239
X6    .962/.933/.959/.944/.932/.925/.913/.866/.870/.866/.762/.765/.930      DH240
C     CCDT*=.969/.952/.990/.871/.884/.770/.925/.922/.987/.959/.976/.991/    DH241
X1    .957/.953/.955/.876/.819/.920/.863/.905/.915/.957/.930/.933/.950/.    DH242
X2    979/.926/.905/.894/.935/.951/.950/.974/.951/.912/.901/.964/.993/.9    DH243
X3    85/.986/.977/.979/.993/.875/.927/.747/.967/.963/.991/.990/.984/.98    DH244
X4    6/.963/.997/.995/.970/.992/.976/.925/.870/.946/.969/.977/.984/.976    DH245
X5    /.955/.950/.969/.901/.966/.980/.982/.987/.964/.989/.987/.993/.984/    DH246
X6    .918/.844/.953/.961/.959/.964/.990/.987/.992/.963/.705/.983/.762      DH247
C     DCDT*=.989/.979/.963/.984/.947/.965/.954/.932/.949/.987/.970/.990/    DH248
X1    .981/.962/.955/.964/.973/.966/.990/.990/.993/.969/.982/.970/.947/.    DH249
X2    955/.979/.990/.950/.972/.751/.984/.987/.969/.965/.947/.937/.985/.9    DH250
X3    63/.969/.993/.997/.993/.997/.980/.980/.990/.995/.993/.997/.995/.94    DH251
X4    3/.892/.906/.945/.910/.969/.969/.926/.967/.956/.917/.749/.947/.621    DH252
X5    /.878/.883/.853/.950/.917/.866/.853/.908/.861/.914/.872/.634/.857/    DH253
X6    .792/.954/.900/.957/.891/.919/.966/.975/.846/.920/.959/.927/.930      DH254
6R    YCIN1.KL=XCIN.K                                                       DH255
6A    YCIN.K=YCIN1.JK                                                       DH256
6R    FRIN4.KL=FRIN1.K                                                      DH257
6A    FRIN3.K=FRIN4.JK                                                      DH258
NOTE
NOTE  INITIAL CONDITIONS
NOTE
6N    DAY=0
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6N     SEA=0
6N     YEARS=1
6N     FRIN4=0
6N     YRIN1=0
6N     YCIN1=0
6N     YCIN=1
6N     YRIN=1
6N     NAST1=1
6N     NBST1=0
NOTE
NOTE   GENERATION OF LOW FLOWS ONLY
NOTE   WILLAMETTE RIVER HYDROLOGY
NOTE
C      WRFOB=6000                                                          WH1
6A     WR.K=WRFOB                        WILL. RIVER FLOW OBJECTIVE        WH2
51A    SUM1.K=CLIP(SUM3.K,66500,DAY.K,241)                                 WH3
51A    FWIN1.K=CLIP(WR.K,WIN1.K,SUMF.K,66500)                              WH4
51A    SUMF.K=CLIP(SUM1.K,66500,364,DAY.K)                                 WH5
52L    SUM3.K=SUM3.J+(DT)(SUM4.JK-SUM5.JK-SUM2.JK-0)                       WH6
51R    SUM4.KL=CLIP(FCIN2.K,0,DAY.K,151)                                   WH7
51R    SUM5.KL=CLIP(FCIN2.K,0,DAY.K,241)                                   WH8
51R    SUM2.KL=CLIP(SUM3.K,0,DAY.K,364)                                    WH9
51A    WIN1.K=CLIP(WIN3.K,WIN2.K,SUMF.K,30000)                             WH10
58A    WIN2.K=TABHL(DRYL,DAY.K,241,373,12)                                 WH11
C      DRYL*=4500/4500/4500/4550/4550/4550/4550/4550/5666/5666/5666/5666   WH12
51A    WIN3.K=CLIP(WIN5.K,WIN4.K,SUMF.K,51000)                             WH13
43A    CURN.K=SAMPLE(-UND.K,364)                                           WH14
33A    UND.K=(2)NOISE                                                      WH15
51A    WIN4.K=CLIP(WNM1.K,WNM2.K,-0.00,CURN.K)                             WH16
58A    WNM1.K=TABHL(DRYM1,DAY.K,241,373,12)                                WH17
C      DRYM1*=7061/7061/7061/4530/4530/4560/4597/4597/7470/7470/7470/7470  WH18
X1                                                                         WH18
58A    WNM2.K=TABHL(DRYM2,DAY.K,241,373,12)                                WH19
C      DRYM2*=7178/7178/7178/5813/5813/5750/5684/5684/6573/6573/6573/6573  WH20
.X1                                                                        WH20
51A    WIN5.K=CLIP(WNW1.K,WNW2.K,-0.50,CURN.K)                             WH21
58A    WNW1.K=TABHL(DRYW1,DAY.K,241,373,12)                                WH22
C      DRYW1*=5400/5400/5400/4550/4550/4610/4676/4676/6633/6633/6633/6633  WH23
X1                                                                         WH23
51A    WNW2.K=CLIP(WNW3.K,WNW4.K,0.0,CURN.K)                               WH24
58A    WNW3.K=TABHL(DRYW2,DAY.K,241,373,12)                                WH25
C      DRYW2*=5540/5540/5540/4642/4642/4660/4680/4680/6035/6035/6035/6035  WH26
X1                                                                         WH26
51A    WNW4.K=CLIP(WNW5.K,WNW6.K,0.5,CURN.K)                               WH27
58A    WNW5.K=TABHL(DRYW3,DAY.K,241,373,12)                                WH28
C      DRYW3*=7073/7073/7073/5350/5350/5180/5004/5004/6704/6704/6704/6704  WH29
X1                                                                         WH29
6A     WNW6.K=WRFOB                                                        WH30
NOTE
NOTE   FLOWS INTO WILLAMETTE RIVER
NOTE
20A    CLVAS.K=CLVA.K/86400                                                FW1
6A     COUTS.K=CLVAS.K                                                     FW2
12R    COUT.KL=(COUTS.K)(86400)                                            FW3
7A     TFWIN.K=FWIN5.K+COUTS.K                                             FW4
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6R      FWIN2.KL=FWIN1.K                                                        FW5
6A      FWIN3.K=FWIN2.JK                                                        FW6
6R      FWIN4.KL=FWIN3.K                                                        FW7
6A      FWIN5.K=FWIN4.JK                                                        FW8
NOTE
NOTE    INITIAL CONDITIONS FOR FLOWS INTO THE WILL. RIVER
NOTE
6N      FWIN2=6000
6N      FWIN4=6000
6N      SUM3=0
NOTE
NOTE    RESERVOIR AND CHANNEL LEVEL
NOTE
NOTE    EVAPORATION
NOTE
4L      RLVA.K=RLVA.J+(DT)(1/43560)(RIN.JK-ROUT.JK-IROUT.JK-EVAPO.JK+0+0)    RCL1
2L      CLVA.K=CLVA.J+(DT)(LROUT.JK+CIN.JK-RIN2.JK+IRRIN.JK-COUT.JK+0)       RCL2
6A      RIN1.K=RIN.JK                                                         RCL3
6R      RIN2.KL=RIN1.K                                                        RCL4
6R      EVAPO.KL=EVAP1.K                                                      RCL5
12A     EVAP1.K=(EVAP2.K)(43560)                                              RCL6
44A     EVAP2.K=(EVAP3.K)(RSA1.K)/1000                                        RCL7
51A     EVAP3.K=CLIP(0,EVAP4.K,181,DAY.K)                                     RCL8
58A     EVAP4.K=TABHL(EVAP,DAY.K,182,377,15)                                  RCL9
C       EVAP*=4/6/8/10/11/12/16/17.2/16/14/12/9.2/6.4/5                       RCL10
58A     RSA1.K=TABHL(RSA,RLVA.K,0,200000,20000)                               RCL11
C       RSA*=0/763/1159/1559/1914/2221/2431/2640/2850/2910/2975               RCL12
NOTE
NOTE    INITIAL CONDITIONS FOR RES. AND CHANN. LEVEL
NOTE
6N      RIN=0
6N      RIN2=0
NOTE
NOTE    RESERVOIR RELEASES
NOTE
6R      LROUT.KL=ROUT.JK                                                      RR1
51R     ROUT.KL=CLIP(ROUT1.K,ROUT2.K,240,DAY.K)                               RR2
51A     ROUT1.K=CLIP(RIN.K,ROUT3.K,RLVA.K,RCAP.K)                             RR3
51A     ROUT3.K=CLIP(0,ROUT4.K,CLVAS.K,CCAP.K)                                RR4
56A     ROUT4.K=MAX(ROUT5.K,MINXX.K)                                          RR5
12A     MINXX.K=(MINX.K)(86400)                                               RR6
51A     MINX.K=CLIP(RMFF1.K,RLVA1.K,RLVA2.K,0)                                RR7
44A     RLVA1.K=(RLVA.K)(43560)/86400                                         RR8
7A      RLVA2.K=RLVA1.K-RMFF1.K                                               RR9
58A     RMFF1.K=TABHL(RMFT,DAY.K,1,376,15)                                    RR10
C       RMFT*=130/130/130/130/130/130/130/130/130/130/130/130/130/130/130/   RR11
X1      130/130/90/90/90/90/90/90/130/130/130                                 RR11
51A     ROUT5.K=CLIP(SPICP.K,RWOPC.K,RWOPC.K,SPICP.K)                         RR12
51A     RWOPC.K=CLIP(RWOP1.K,CDLC.K,CDLC.K,RWOP1.K)                           RR13
51A     CDLC.K=CLIP(CCPLA.K,0,DCHLV.K,CLVA.K)                                 RR14
7A      CCPLA.K=DCHLV.K-CLVA.K                                                RR15
7A      DCHLV.K=CCAPD.K-SAFNO.K                                               RR16
6A      SAFNO.K=SAFNU          SAFTEY NO. TO REDUCE CHANNEL CAPACITY          RR17
C       SAFNU=4434E+03             CHCAP=21000  =132 CFS                      RR18
6A      SPICP.K=SPICA                                  SPILLWAY CAPACITY      RR19
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C      SPICA=4717E+06                                                        RR20
51A    RWOP1.K=CLIP(RWOPA.K,0,RLVA.K,RWOPL.K)                               RR21
15A    RWOPA.K=(RLVA.K)(43560)+(-RWOPL.K)(43560)                            RR22
12A    RWOPL.K=(RCAP.K)(RWOPP.K)                                            RR23
58A    RWOPP.K=TABHL(WOPT,DAY.K,1,376,15)                                   RR24
C      WOPT*=.90/.80/.60/.50/.40/.40/.44/.54/.61/.66/.73/.77/.87/.91/.95/  RR25
X1     .98/.98/.98/.98/.98/.98/.98/.96/.95/.90/.90      RULE 16             RR25
7A     ROT2.K=FIRL1.K+WQRL1.K                                               RR26
12A    ROUT2.K=(ROT2.K)(86400)            FT. CU./DAY                       RR27
NOTE
NOTE   VOLUME  AVAILABLE  FOR  DISTRIBUTION
NOTE
10A    VOL01.K=RLVA.K-CP06.K+EXRSI.K-FD06.K-WQDOT.K+0 (UNITS AC FT )       RR28
12A    CP06.K=(0.6)(MICVP.K)                                                RR29
51A    EXRSI.K=CLIP(ERSI1.K,0,ERSI1.K,0)                                    RR30
13A    ERSI1.K=(EXPFS.K)(ERSI2.K)(2)  CONV. SFD TO AC. FT.                 RR31
6A     EXPFS.K=EPFS                        FRACTION OF AVE. SUMMER FLOW     RR32
C      EPFS=0.90                                                            RR33
7A     ERSI2.K=EXSIF.K-SIFTD.K          DIF. BETWEEN EXP. AND ACT.          RR34
14A    EXSIF.K=8260+(0.029)(SUM3.K)                                         RR35
1L     SIFTD.K=SIFTD.J+(DT)(FRINS.JK-TFRNS.JK)                              RR36
51R    FRINS.KL=CLIP(FRIN1.K,0,DAY.K,241)                                   RR37
51R    TFRNS.KL=CLIP(SIFTD.K,0,1,DAY.K)                                     RR38
13A    FD06.K=(0.6)(FIDMR.K)(2)  60 PERCENT FISH.  CONV. CFS TO AC. FT.     RR39
7A     FIDMR.K=FIDMD.K-FIRLS.K                                              RR40
6A     FIDMD.K=12520  (SFD) (INCLUDES COMPL. FROM WATER QUALITY)           RR41
52L    FIRLS.K=FIRLS.J+(DT)(RMFF7.JK+RMFF8.JK+0-TRMFF.JK)                   RR42
12A    RMFF2.K=(0.6)(RMFF3.K)                                               RR43
6R     RMFF7.KL=RMFF2.K                                                     RR44
6R     RMFF8.KL=RMFF3.K                                                     RR45
51A    RMFF3.K=CLIP(RMFF1.K,0,DAY.K,241)                                    RR46
51R    TRMFF.KL=CLIP(FIRLS.K,0,1,DAY.K)                                     RR47
NOTE
NOTE   WATER QUALITY DEMANDS CONSIDERING COMPLEMENT FROM FISH
NOTE
51A    WQDOT.K=CLIP(WQD02.K,WQD01.K,SUMF.K,30000) W.Q. DEM. FOR ICR. 1,2    RR48
18A    WQD01.K=(2)(DRL12.K-WQR01.K)     CONV. SFD TO AC. FT.               RR49
C      DRL12=0  (SFD)  Q=5000                                               RR50
1L     WQR01.K=WQR01.J+(DT)(WQR2.JK-TWQ01.JK)                               RR51
6R     WQR2.KL=WQR02.K                                                      RR52
51R    TWQ01.KL=CLIP(WQR01.K,0,DAY.K,364)                                   RR53
51A    WQR02.K=CLIP(WQRX2.K,0,DAY.K,241)                                    RR54
58A    WQRX2.K=TABHL(DL12,DAY.K,241,373,12)                                 RR55
C      DL12*=0/0/0/0/0/0/0/0/0/0/0/0  Q=5000                                RR56
51A    WQD02.K=CLIP(WQD04.K,WQD03.K,SUMF.K,51000)                           RR57
51A    WQD03.K=CLIP(WQD05.K,WQD06.K,-0.0,CURN.K)                            RR58
18A    WQD05.K=(2)(DRM12.K-WQR03.K)   CONV. SFD TO AC. FT.                 RR59
6A     DRM12.K=312    (SFD)  Q=5000                                         RR60
1L     WQR03.K=WQR03.J+(DT)(WQR4.JK-TWQ03.JK)                               RR61
6R     WQR4.KL=WQR04.K                                                      RR62
51R    TWQ03.KL=CLIP(WQR03.K,0,DAY.K,364)                                   RR63
58A    WQR04.K=TABHL(DM12,DAY.K,241,373,12)                                 RR64
C      DM12*=0/0/0/13/13/0/0/0/0/0/0/0     Q=5000                           RR65
6A     WQD06.K=0          NO WATER QUALITY DEMAND                           RR66
51A    WQD04.K=CLIP(WQD06.K,WQD07.K,SUMF.K,66500)                           RR61
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51A     WQD07.K=CLIP(WQD08.K,WQD09.K,-0.5,CURN.K)                        RR68
18A     WQD08.K=(2)(DRW12.K-WQR05.K)                                     RR69
C       DRW12=1872    (SFD)    G=5000                                    RR70
1L      WQR05.K=WQR05.J+(DT)(WQR6.JK-TWQ05.JK)                           RR71
6R      WQR6.KL=WQR06.K                                                  RR72
51R     TWQ05.KL=CLIP(WQR05.K,0,DAY.K,364)                               RR73
58A     WQR06.K=TABHL(DW12,DAY.K,241,373,12)                             RR74
C       DW12*=0/0/0/72/72/12/0/0/0/0/0/0    G=5000                       RR75
51A     WQD09.K=CLIP(WQD10.K,WQD06.K,0.0,CURN.K)                         RR76
18A     WQD10.K=(2)(DRW21.K-WQR07.K)    CONV. SFD TO AC. FT.             RR77
6A      DRW21.K=0     (SFD)    G=5000                                    RR78
1L      WQR07.K=WQR07.J+(DT)(WQR8.JK-TWQ07.JK)                           RR79
6R      WQR8.KL=WQR08.K                                                  RR80
51R     TWQ07.KL=CLIP(WQR07.K,0,DAY.K,364)                               RR81
58A     WQR08.K=TABHL(DW21,DAY.K,241,373,12)                             RR82
C       DW21*=0/0/0/0/0/0/0/0/0/0/0/0    G=5000                          RR83
51A     FRLS1.K=CLIP(RMFF2.K,RMFF4.K,VOL01.K,0)    FISH RELEASE, FIRST INCR  RR84
7A      AVFR.K=FD06.K+VOL01.K         VOL. AVAIL FOR FISH REL. AC. FT.   RR85
12A     RMFF4.K=(RMFF2.K)(RDFF.K)                                        RR86
56A     RDFF.K=MAX(RDFF1.K,RDFF2.K)  REDUCED FISH FLOW FACTOR            RR87
20A     RDFF1.K=AVFR.K/FD06X.K                                           RR88
49A     FD06X.K=SWITCH(100,FD06.K,FD06.K)                                RR89
20A     RDFF2.K=RLVA.K/MICVP.K                                           RR90
NOTE
NOTE    IRRIGATION ALLOCATION AND ROUTING
NOTE
14A     VOL02.K=VOL01.K+(-0.8)(IRRNA.K)                                  RR91
12A     IRRNA.K=(IRRN3.K)(NIRTF.K)                                       RR92
20A     NIRTF.K=NIRGT.K/69900          NEW IRRIG. TARGET FACTOR          RR93
6A      NIRGT.K=TIRR                               IRRIGATION TARGET     RR94
C       TIRR=84000                                                       RR95
58A     IRRN3.K=TABHL(IRNT,DAY.K,182,392,30)                             RR96
C       IRNT*=69900/67800/61500/45800/20800/2100/0.1/0.1                 RR97
NOTE
NOTE    IRRIGATION RELEASE (FIRST INCREMENT)
NOTE
13A     IRRN1.K=(0.8)(IRNM.K)(NIRGT.K)      IRRIG. REL. AC. FT.          RR98
58A     IRNM.K=TABHL(IRNM1,DAY.K,182,377,15)                             RR99
C       IRNM1*=0/.001/.002/.00270/.00467/.00667/.012/.012/.012/.01067/.002  RR100
X1      /.001/0/0                                                        RR101
51A     IR01.K=CLIP(IR02.K,0,VOL01.K,0)                                  RR102
51A     IR02.K=CLIP(IRRN1.K,IRRN2.K,VOL02.K,0)                           RR103
46A     IRRN2.K=(IRRN1.K)(AVIR.K)(1)/((IRRN3.K)(NIRTF.K)(0.8))           RR104
14A     AVIR.K=VOL02.K+(0.8)(IRRNA.K)                                    RR105
NOTE
NOTE    NEXT INCREMENT FOR FISH AND WATER QUALITY
NOTE
8A      VOL03.K=VOL02.K-CP04.K-FD04.K                                    RR106
12A     CP04.K=(0.4)(MICVP.K)                                            RR107
14A     FD04.K=-WQDOT.K+(0.8)(FIDMR.K) 40 PERCENT FISH, CONV. SFD TO AC FT  RR108
12A     RMFF5.K=(0.4)(RMFF3.K)                                           RR109
49A     FD04X.K=SWITCH(100,FD04.K,FD04.K)                                RR110
44A     RMFF6.K=(RMFF5.K)(AVFR2.K)/FD04X.K                               RR111
51A     AVFR2.K=CLIP(AXFR2.K,0,AXFR2.K,0)                                RR112
7A      AXFR2.K=FD04.K+VOL03.K  SECOND INCR. AVAIL. FISH RELEASE AC. FT.   RR113
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51A     FRLS2.K=CLIP(RMFF5.K,RMFF6.K,VOL03.K,0) FISH REL. SECOND INCREMENT  RR114
51A     FRLS3.K=CLIP(FRLS4.K,0,VOL02.K,0)                                   RR115
7A      FRLS4.K=FRLS2.K-WQ101.K                                             RR116
NOTE
NOTE    SECOUND INCREMENT FOR IRRIGATION
NOTE
14A     VOL04.K=VOL03.K+(-0.2)(IRRNA.K)                                     RR117
13A     IRRN3.K=(0.2)(IRNM.K)(NIRGT.K) IRRIG. RELEASE IN AC-FT              RR118
51A     IR03.K=CLIP(IR04.K,0,VOL03.K,0)                                     RR119
51A     IR04.K=CLIP(IRRN3.K,IRRN4.K,VOL04.K,0)                              RR120
46A     IRRN4.K=(IRRN3.K)(AVIR2.K)(1)/((IRRNB.K)(0.2)(NIRTF.K))             RR121
14A     AVIR2.K=VOL04.K+(0.2)(IRRNA.K)                                      RR122
NOTE
NOTE    ADD AN INCREMENT OF STORAGE FOR RECREATION AND RESERVOIR SPORT FI
NOTE
14A     VOL05.K=VOL04.K+(-0.2)(MICVP.K)                                     RR123
NOTE
NOTE    RELEASE FOR THIRD INCREMENT OF WATER QUALITY
NOTE    CONSIDER COMPLEMENT FROM FISH
NOTE
7A      VOL06.K=VOL05.K-RWQDT.K                                             RR124
51A     RWQDT.K=CLIP(RWQD2.K,RWQD1.K,SUMF.K,30000)                          RR125
18A     RWQD1.K=(2)(DRL3.K-RWQ01.K) CONVERTS SFD TO AC-FT                   RR126
6A      DRL3.K=LDR3                                                         RR127
C       LDR3=33749              (SFD)         Q=5000                        RR128
1L      RWQ01.K=RWQ01.J+(DT)(RWQ02.JK-TRWQ1.JK)                             RR129
51R     TRWQ1.KL=CLIP(RWQ01.K,0,DAY.K,364)                                  RR130
51R     RWQ02.KL=CLIP(RWQX2.K,0,DAY.K,241)                                  RR131
58A     RWQX2.K=TABHL(DL3,DAY.K,241,373,12).                                RR132
C       DL3*=370/402/410/360/360/360/360/360/0/0/0/0      Q=5000            RR133
51A     RWQD2.K=CLIP(RWQD4.K,RWQD3.K,SUMF.K,51000)                          RR134
51A     RWQD3.K=CLIP(RWQD5.K,RWQD6.K,-0.0,CURN.K)                           RR135
18A     RWQD5.K=(2)(DRM3.K-RWQ03.K) CONV SFD TO AC-FT                       RR136
6A      DRM3.K=MDR3                                                         RR137
C       MDR3=20832          (SFD)                 Q=5000                    RR138
1L      RWQ03.K=RWQ03.J+(DT)(RWQ04.JK-TRWQ3.JK)                             RR139
51R     TRWQ3.KL=CLIP(RWQ03.K,0,DAY.K,364)                                  RR140
58R     RWQ04.KL=TABHL(DM3,DAY.K,241,373,12)                                RR141
C       DM3*=0/0/0/380/380/350/313/313/0/0/0/0              Q=5000          RR142
6A      RWQD6.K=0   NO WATER QUALITY DEMAND                                 RR143
51A     RWQD4.K=CLIP(RWQD6.K,RWQD7.K,SUMF.K,66500)                          RR144
51A     RWQD7.K=CLIP(RWQD8.K,RWQD9.K,-0.5,CURN.K)                           RR145
18A     RWQD8.K=(2)(DRW31.K-RWQ05.K) CONV SFD TO AC-FT                      RR146
6A      DRW31.K=WDR31                                                       RR147
C       WDR31=16992        (SFD)               Q=5000                       RR148
1L      RWQ05.K=RWQ05.J+(DT)(RWQ06.JK-TRWQ5.JK)                             RR149
51R     TRWQ5.KL=CLIP(RWQ05.K,0,DAY.K,364)                                  RR150
58R     RWQ06.KL=TABHL(DW31,DAY.K,241,373,12)                               RR151
C       DW31*=0/0/0/324/324/300/234/234/0/0/0/0             Q=5000          RR152
51A     RWQD9.K=CLIP(RWQD0.K,RWQD6.K,0.0,CURN.K)                            RR153
18A     RWQD0.K=(2)(DRW33.K-RWQ07.K) CONV SFD TO AC-FT                      RR154
6A      DRW33.K=WDR33                                                       RR155
C       WDR33=14952             (SFD)             Q=5000                    RR156
1L      RWQ07.K=RWQ07.J+(DT)(RWQ08.JK-TRWQ7.JK)                             RR157
51R     TRWQ7.KL=CLIP(RWQ07.K,0,DAY.K,364)                                  RR158
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58R     RWQ08.KL=TABHL(DW33,DAY.K,241,373,12)                                  RR159
C       DW33*=0/0/0/268/268/250/230/230/0/0/0/0                Q=5000           RR160
51A     WQ301.K=CLIP(WQ302.K,0,VOL05.K,0)                                      RR161
51A     WQ302.K=CLIP(WQ303.K,WQ304.K,VOL06.K,0)                                RR162
49A     RWQDX.K=SWITCH(100,RWQDT.K,RWQDT.K)                                    RR163
44A     WQ304.K=(WQ303.K)(AVWQ3.K)/RWQDX.K                                     RR164
7A      AVWQ3.K=RWQDT.K+VOL06.K                                                RR165
NOTE
NOTE    FINAL INCREMENT FOR WATER QUALITY
NOTE
7A      VOL07.K=VOL06.K-XWQDT.K                                                RR166
51A     XWQDT.K=CLIP(XWQD2.K,XWQD1.K,SUMF.K,30000)                             RR167
18A     XWQD1.K=(2)(DRL4.K-XWQ01.K)         CONVERTS SFD TO AC. FT.            RR168
6A      DRL4.K=LDR4                                                            RR169
C       LDR4=99650    (SFD)   Q = 6000                                         RR170
1L      XWQ01.K=XWQ01.J+(DT)(XWQ02.JK-TXWQ1.JK)                                RR171
51R     TXWQ1.KL=CLIP(XWQ01.K,0,DAY.K,364)                                     RR172
51R     XWQ02.KL=CLIP(XWQX2.K,0,DAY.K,241)                                     RR173
58A     XWQX2.K=TABHL(DL4,DAY.K,241,373,12)                                    RR174
C       DL4*=1000/1000/1000/1000/1000/1000/1000/1000/244/204/204/204 Q6000     RR175
51A     XWQD2.K=CLIP(XWQD4.K,XWQD3.K,SUMF.K,51000)                             RR176
51A     XWQD3.K=CLIP(XWQD5.K,XWQDC.K,-0.0,CURN.K)                              RR177
18A     XWQD5.K=(2)(DRM4.K-XWQ03.K)         CONV. SFD TO AC. FT.               RR178
6A      DRM4.K=MDR4                                                            RR179
C       MDR4=60000            (SFD)        Q=6000                              RR180
1L      XWQ03.K=XWQ03.J+(DT)(XWQ04.JK-TXWQ3.JK)                                RR181
51R     TXWQ3.KL=CLIP(XWQ03.K,0,DAY.K,364)                                     RR182
58R     XWQ04.KL=TABHL(DM4,DAY.K,241,373,12)                                   RR183
C       DM4*=0/0/0/1000/1000/1000/1000/1000/0/0/0/0            Q=6000          RR184
18A     XWQDC.K=(2)(DRM42.K-XWQ11.K)                                           RR185
6A      DRM42.K=MDR42                                                          RR186
C       MDR42=9672      (SFD)      Q=6000                                      RR187
1L      XWQ11.K=XWQ11.J+(DT)(XWQ12.JK-TXWQ0.JK)                                RR188
51R     TXWQ0.KL=CLIP(XWQ11.K,0,DAY.K,364)                                     RR189
58R     XWQ12.KL=TABHL(DM42,DAY.K,241,373,12)                                  RR190
C       DM42*=0/0/0/97/97/100/228/228/0/0/0/0           Q=6000                 RR191
6A      XWQD6.K=0             NO WATER QUALITY DEMAND                          RR192
51A     XWQD4.K=CLIP(XWQD6.K,XWQD7.K,SUMF.K,66500)                             RR193
51A     XWQD7.K=CLIP(XWQD8.K,XWQD9.K,-0.5,CURN.K)                              RR194
18A     XWQD8.K=(2)(DRW41.K-XWQ05.K)     CONVERT SFD TO AC-FT                  RR195
6A      DRW41.K=WDR41                                                          RR196
C       WDR41=74815           (SFD)      Q=6000                                RR197
1L      XWQ05.K=XWQ05.J+(DT)(XWQ06.JK-TXWQ5.JK)                                RR198
51R     TXWQ5.KL=CLIP(XWQ05.K,0,DAY.K,364)                                     RR199
58R     XWQ06.KL=TABHL(DW41,DAY.K,241,373,12)                                  RR200
C       DW41*=470/470/510/1000/1000/1000/1000/1000/0/0/0/0          Q=6000     RR201
51A     XWQD9.K=CLIP(XWQD0.K,XWQDA.K,0.0,CURN.K)                               RR202
18A     XWQD0.K=(2)(DRW44.K-XWQ07.K)     CONVERT SFD TO AC-FT                  RR203
6A      DRW44.K=WDR44                                                          RR204
C       WDR44=70545      (SFD)       Q=6000                                    RR205
1L      XWQ07.K=XWQ07.J+(DT)(XWQ08.JK-TXWQ7.JK)                                RR206
51R     TXWQ7.KL=CLIP(XWQ07.K,0,DAY.K,364)                                     RR207
58R     XWQ08.KL=TABHL(DW44,DAY.K,241,373,12)                                  RR208
C       DW44*=330/330/370/1000/1000/1000/1000/1000/0/0/0/0          Q=6000     RR209
51A     XWQDA.K=CLIP(XWQDB.K,XWQD6.K,0.5,CURN.K)                               RR210
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18A     XWQDD.K=(2)(DRW43.K-XWQ09.K)                                                  RR211
6A      DRW43.K=WDR43                                                                 RR212
C       WDR43=43944      (SFD)         G=6000                                         RR213
1L      XWQ09.K=XWQ09.J+(DT)(XWQ10.JK-TXWQ9.JK)                                       RR214
51R     TXWQ9.KL=CLIP(XWQ09.K,0,DAY.K,364)                                            RR215
58R     XWQ10.KL=TABHL(DW43,DAY.K,241,373,12)                                         RR216
C       DW43*=0/0/0/560/560/730/906/906/0/0/0/0           G=6000                      RR217
51A     WQ401.K=CLIP(WQ402.K,0,VOL06.K,0)                                             RR218
51A     WQ402.K=CLIP(WQ403.K,WQ404.K,VOL07.K,0)                                       RR219
44A     WQ404.K=(WQ403.K)(AVWQ4.K)/XWQDX.K                                            RR220
7A      AVWQ4.K=XWQDT.K+VOL07.K                                                       RR221
49A     XWQDX.K=SWITCH(100,XWQDT.K,XWQDT.K)                                           RR222
NOTE
NOTE    RESERVOIR RELEASES FOR FISH AND WATER QUALITY
NOTE
7A      FIRL1.K=FRLS1.K+FRLS3.K                                                       RR223
8A      WQRL1.K=WQ101.K+WQ301.K+WQ401.K                                               RR224
51A     WQ101.K=CLIP(WQ102.K,WQR02.K,SUMF.K,30000)                                    RR225
51A     WQ102.K=CLIP(WQ104.K,WQ103.K,SUMF.K,51000)                                    RR226
51A     WQ103.K=CLIP(WQR04.K,0,-0.0,CURN.K)                                           RR227
51A     WQ104.K=CLIP(0,WQ107.K,SUMF.K,66500)                                          RR228
51A     WQ107.K=CLIP(WQR06.K,WQ109.K,-0.5,CURN.K)                                     RR229
51A     WQ109.K=CLIP(WQR08.K,0,0.0,CURN.K)                                            RR230
51A     WQ303.K=CLIP(WQ32.K,RWQ02.JK,SUMF.K,30000)                                    RR231
51A     WQ32.K=CLIP(WQ34.K,WQ33.K,SUMF.K,51000)                                       RR232
51A     WQ33.K=CLIP(RWQ04.JK,0,-0.0,CURN.K)                                           RR233
51A     WQ34.K=CLIP(0,WQ37.K,SUMF.K,66500)                                            RR234
51A     WQ37.K=CLIP(RWQ06.JK,WQ39.K,-0.5,CURN.K)                                      RR235
51A     WQ39.K=CLIP(RWQ08.JK,0,0.0,CURN.K)                                            RR236
51A     WQ403.K=CLIP(WQ42.K,XWQ02.JK,SUMF.K,30000)                                    RR237
51A     WQ42.K=CLIP(WQ44.K,WQ43.K,SUMF.K,51000)                                       RR238
51A     WQ43.K=CLIP(XWQ04.JK,XWQ12.JK,-0.0,CURN.K)                                    RR239
51A     WQ44.K=CLIP(0,WQ47.K,SUMF.K,66500)                                            RR240
51A     WQ47.K=CLIP(XWQ06.JK,WQ48.K,-0.5,CURN.K)                                      RR241
.51A    WQ48.K=CLIP(XWQ08.JK,WQ49.K,0.0,CURN.K)                                       RR242
51A     WQ49.K=CLIP(XWQ10.JK,0,0.5,CURN.K)                                            RR243
NOTE    INITIAL CONDITIONS FOR RESERVOIR ROUTING
NOTE
6N      LROUT=0
6N      ROUT=0
6N      SIFTD=0
6N      TFRNS=0
6N      FIRLS=0
6N      TRMFF=0
6N      WQR01=0
6N      TWQ01=0
6N      WQR03=0
6N      TWQ03=0
6N      WQR05=0
6N      TWQ05=0
6N      WQR07=0
6N      TWQ07=0

6N      RWQ01=0
6N      TRWQ1=0
6N      RWQ03=0
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6N     TRWG3=0
6N     RWGQ5=0
6N     TRWG5=0
6N     RWGQ7=0
6N     TRWG7=0
6N     FRINS=0
6N     RWFF7=0
6N     RWFF8=0
6N     WQR2=0
6N     WQR4=0
6N     WQR6=0
6N     WQR8=0
6N     RWGQ2=0
6N     RWGQ4=0
6N     RWGQ6=0
6N     RWGQ8=0
6N     XWGQ1=0
6N     TXWQ1=0
6N     XWGQ2=0
6N     XWGQ3=0
6N     TXWQ3=0
6N     XWGQ4=0
6N     XWGQ5=0
6N     TXWG5=0
6N     XWGQ6=0
6N     XWGQ7=0
6N     TXWG7=0
6N     XWGQ8=0
6N     XWGQ9=0
6N     TXWG9=0
6N     XWG10=0
6N     XWG11=0
6N     TXWG11=0
6N     XWG12=0
NOTE   ROUTING ANALYSIS
NOTE   MXRL USED IN RA1 IS DEFINED IN E2
NOTE
51A    DAMRL.K=CLIP(DMRL.JK,DAY.K,MXRL.JK,RL1.K) DAY MAX RES LEV FOR FLDS  RA1
51A    RL1.K=CLIP(0,RLVA.K,DAY.K,182)                                      RA2
51A    DMRL.KL=CLIP(0,DAMRL.K,DAY.K,364)                                   RA3
51A    DAM3D.K=CLIP(DM3D.JK,DAY.K,MX3D.JK,FR3DT.K) DAY OF MAX 3DAY FLOW    RA4
51A    MX3D.KL=CLIP(0,MX3D1.K,DAY.K,364)                                   RA5
51A    MX3D1.K=MAX(FR3DT.K,MX3D.JK)                                        RA6
51A    DM3D.KL=CLIP(0,DAM3D.K,DAY.K,364)                                   RA7
51A    DMR3S.K=CLIP(DMRL3.JK,DAY.K,MXRL.JK,RLVA.K) MX DAY RLVA 3 SEASONS   RA8
51A    DMRL3.KL=CLIP(0,DMR3S.K,DAY.K,364)                                  RA9
51A    DAMIR.K=CLIP(DAMI.JK,DAY.K,RLVA.K,MINRL.JK)                         RA10
51A    DAMI.KL=CLIP(0,DAMIR.K,DAY.K,364)                                   RA11
NOTE
NOTE   INITIAL CONDITIONS FOR ROUTING ANALYSIS
NOTE
6N     DM3D=0
6N     MX3D=0
6N     DMRL=0
6N     DMRL3=0
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6N      DAMI=0
NOTE
NOTE    DRAINAGE BENEFIT CALCULATION
NOTE
58A     ATDRB.K=TABHL(ATDBT,CCAP.K,5000,21000,2000)                         DB1
C       ATDBT*=0/66667/133333/200000/260000/320000/380000/440000/500000     DB2
42A     PRCLV.K=ACLVA.K/((CCAP.K)(86400))      PROP  CHANNEL FULL           DB3
3L      ACLVA.K=ACLVA.J+(DT)(1/DDR.J)(RCLVA.JK-CLVAO.JK) AVE CHANNEL LEVEL  DB4
51R     RCLVA.KL=CLIP(CLVAA.K,0,DAY.K,151)                                  DB5
51A     CLVAA.K=CLIP(0,CLVA.K,DAY.K,273)                                    DB6
51R     CLVAO.KL=CLIP(ACLVA.K,0,DAY.K,364)                                  DB7
51A     DDR.K=CLIP(1,122,DAY.K,273)                                         DB8
58A     PRDTM.K=TABHL(PDTMT,PRCLV.K,0,1,0.1)                                DB9
C       PDTMT*=1/1/1/1/.8/.6/.4/.3/.2/.1/0                                  DB10
12A     ANDRB.K=(PRDTM.K)(ATDRB.K)                                          DB11
51A     ADBR.K=CLIP(ANDRB.K,0,DAY.K,364)                                    DB12
NOTE
NOTE    FLOOD LOSS
NOTE
58A     TRCIS.K=TABHL(CODIT,FCIN2.K,0,45000,5000)                           FL1
C       CODIT*=19/5199/11244/17289/23334/29379/35424/41469/47514/53559      FL2
56A     MTIN.K=MAX(MIN.JK,TRCIS.K)                                          FL3
51R     MIN.KL=CLIP(0,MTIN.K,DAY.K,364)                                     FL4
58A     FLDLP.K=TABHL(FLDLT,FLDSH.K,10,18,1) FLOOD LOSS POTENTIAL           FL5
C       FLDLT*=0/0/2200/5500/16000/40000/200000/14E5/44E5                   FL6
51A     FDLPR.K=CLIP(FLDLP.K,0,DAY.K,364)    FLOOD LOSS POTENTIAL (ANN.)    FL7
58A     FLDSH.K=TABHL(FLDST,MTIN.K,0,90000,10000) FLOOD STAGE AT SHEDD      FL8
C       FLDST*=10/15.75/16.6/16.9/17.15/17.3/17.5/17.65/17.82/18            FL9
58A     CLVAI.K=TABHL(CODIT,CLVAS.K,0,45000,5000)                           FL10
56A     MCLVA.K=MAX(MCLV.JK,CLVAI.K)                                        FL11
51R     MCLV.KL=CLIP(0,MCLVA.K,DAY.K,364)                                   FL12
58A     AFLDS.K=TABHL(FDST1,MCLVA.K,0,90000,10000)                          FL13
C       FDST1*=10/11/14/15.1/15.75/16.15/16.35/16.5/16.6/16.7               FL14
58A     FDLAR.K=TABHL(FLDLT,AFLDS.K,10,18,1) FLOOD LOSS ACTUAL ANN          FL15
51A     FDLR.K=CLIP(FDLAR.K,0,DAY.K,364)                                    FL16
6A      MIOFL.K=MXIOL                               MAX INST.               FL17
C       MXIOL=10000             NO $ LOSS CHCAP 21000                       FL18
NOTE
NOTE    INITIAL CONDITIONS FOR FLOOD LOSS
NOTE
6N      MCLV=1
6N      MIN=1
NOTE
NOTE    FLOOD BENEFIT CALCULATION
NOTE
8A      AFLD1.K=FDLPR.K-FDLR.K+WILFB.K                   ANN FLOOD BENE.    FBC1
51A     WILFB.K=CLIP(WLFB1.K,0,DAY.K,364)                                   FBC2
6A      WLFB2.K=WFB2  ANN. AVE. WILL. RIVER FLOOD BENEFIT                   FBC3
C       WFB2=160000                                                         FBC4
6R      FRIN5.KL=FRIN3.K                                                    FBC5
6A      FRIN6.K=FRIN5.JK                                                    FBC6
19A     FR3DT.K=(2)(FRIN1.K+FRIN3.K+FRIN6.K+0)                              FBC7
7A      AVFST.K=RCAP.K-RLVA.K                                               FBC8
7A      INSUF.K=FR3DT.K-AVFST.K                                             FBC9
51A     FADJ1.K=CLIP(INSUF.K,0,INSUF.K,0)                                   FBC10
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51A    FADJT.K=CLIP(0,FADJ1.K,DAY.K,182)                                   FBC11
6A     TGFDS.K=TFDS                                 TARGET FLOOD STORAGE   FBC12
C      TFDS=60000                                                          FBC13
50A    WLFB3.K=(WLFB2.K)(TGFDS.K)/(TGFDS.K+FADJT.K)                        FBC14
54A    WLFB1.K=MIN(WLFB4.JK,WLFB3.K)                                       FBC15
51R    WLFB4.KL=CLIP(160000,WLFB1.K,DAY.K,364)                             FBC16
6N     WLFB4=160000
NOTE
NOTE   IRRIGATION RETURN FLOWS
NOTE
12R    IRRIN.KL=(PERRF)(IROUT.JK)                                          IR1
C      PERRF=.15                         PERCENT RETURN OF IRR. FLOW       IR2
7A     IR05.K=IR01.K+IR03.K             AC. FT.                            IR3
12R    IROUT.KL=(IR05.K)(43560)                                            IR4
NOTE
NOTE   IRRIGATION BENEFIT CALCULATION
NOTE
12A    ANIB.K=(NIRTF.K)(552690)                    ANNUAL TARGET BENEFIT   IB1
1L     TIROT.K=TIROT.J+(DT)(IROUT.JK-ACIRO.JK)                             IB2
51R    ACIRO.KL=CLIP(TIROT.K,0,DAY.K,364)                                  IB3
20A    TIRO.K=TIROT.K/43560                                                IB4
20A    PERTM.K=TIRO.K/NIRGT.K                                              IB5
58A    PERAB.K=TABHL(PAB,PERTM.K,0,1.0,0.1)                                IB6
C      PAB*=-.72/-.54/-.36/-.18/0/.18/.36/.54/.72/.86/1.0                  IB7
12A    ANIBH.K=(PERAB.K)(ANIB.K)                                           IB8
51A    AIB.K=CLIP(ANIBH.K,0,DAY.K,364)                                     IB9
NOTE
NOTE   FISH BENEFIT CALCULATION
NOTE
54A    MICLS.K=MIN(MICL1.JK,PMICL.K)                                       FB1
51R    MICL1.KL=CLIP(MICLS.K,20,DAY.K,2)                                   FB2
20A    PMICL.K=CLVAS.K/RMFF1.K                                             FB3
20A    PMIRL.K=RLVA.K/MICVP.K                                              FB4
6A     MICVP.K=MINPL           MINIMUM CONSER. POOL  CANNOT BE ZERO        FB5
C      MINPL=51000                                                         FB6
54A    MIRL.K=MIN(MIRL1.JK,PMIRL.K)                                        FB7
51R    MIRL1.KL=CLIP(20,MIRL.K,DAY.K,364)                                  FB8
54A    MICRL.K=MIN(MICLS.K,MIRL.K)                                         FB9
51A    MICR3.K=CLIP(MICR1.K,0,DAY.K,364)                                   FB10
54A    MICR1.K=MIN(MICR2.JK,MICRL.K)                                       FB11
51R    MICR2.KL=CLIP(MICR1.K,20,DAY.K,2)                                   FB12
51A    MIPCP.K=CLIP(MIRL.K,0,DAY.K,364)                                    FB13
58A    PFBRS.K=TABHL(PTFIB,MIPCP.K,0,1.2,0.2)                              FB14
C      PTFIB*=0/.05/.2/.6/.8/1.0/1.05                                      FB15
12A    FIBRS.K=(PFBRS.K)(RSFB.K)                                           FB16
6A     RSFB.K=RSFIB                      RESERVOIR SPORT FISH BENEFIT      FB17
C      RSFIB=154000                                                        FB18
58A    PFBAD.K=TABHL(PFIB1,MICR3.K,0,1.2,0.2)                              FB19
C      PFIB1*=0/0/0/.6/.8/1.0/1.05                                         FB20
12A    FIBAD.K=(PFBAD.K)(ADFB.K)                                           FB21
6A     ADFB.K=ADFIB       ANNUAL ANADROMOUS AND DOWNSTREAM FISH BENEFIT    FB22
C      ADFIB=424000                                                        FB23
7A     FB.K=FIBRS.K+FIBAD.K                    TOTAL ANN GROSS FISH BENE.  FB24
C      INFC=800000                                    INITIAL  FISH  COST  FB25
6A     INFC1.K=INFC                                                        FB26
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18A     FCST.K=(INFC1.K)(CRF50.K+.10)     FISH COST                               FB27
51A     AFCST.K=CLIP(FCST.K,0,DAY.K,364)               ANN. FISH COST             FB28
NOTE
NOTE    INITIAL CONDITIONS FOR FISH BENEFIT CALC.
NOTE
6N      MICL1=2
6N      MICR2=2
6N      MIRL1=2
NOTE
NOTE    WATER QUALITY BENEFITS
NOTE
54A     MIFWR.K=MIN(MIFW1.JK,PMIFW.K)                                             WQ1
51R     MIFW1.KL=CLIP(MIFWR.K,20,DAY.K,2)                                         WQ2
26A     PMIFW.K=(TFWIN.K-4500+0)/(WQOBJ.K-4500+0)                                 WQ3
6A      WQOBJ.K=WQBJ   WATER QUALITY OBJECTIVES                                   WQ4
C       WQBJ=6000                                                                 WQ5
51A     MIPWQ.K=CLIP(MIFWR.K,0,DAY.K,364)                                         WQ6
51A     PWQB.K=CLIP(1,MIPWQ.K,MIPWQ.K,1)                                          WQ7
15A     WAQB.K=(PWQB.K)(WQBN.K)+(CRF20.K)(INPLC.K)                                WQ8
6A      WQBN.K=WQB  WATER QUALITY BENEFIT                                         WQ9
C       WQB=244600            Q6000 D5  M1000                                     WQ10
6A      INPLC.K=INPC                                                              WQ11
C       INPC=7.56E6       Q6000 D5 M1000                                          WQ12
51A     AWAQB.K=CLIP(WAQB.K,0,DAY.K,364)             ANN. WATER QUAL. BENE.       WQ13
NOTE
NOTE    INITIAL CONDITIONS FOR WATER QUALITY BENEFITS
NOTE
6N      MIFW1=2
NOTE
NOTE    RECREATION BENEFITS
NOTE
58A     PLELV.K=TABHL(PLEV,RLVA.K,0,200000,20000)                                 RB1
C       PLEV*=560/602/620/638/651/661/669/677/685/692/699                         RB2
58A     MXPL.K=TABHL(PLEV,RCAP.K,0,200000,20000)           MAX POOL ELEV          RB3
7A      PLDRP.K=MXPL.K-PLELV.K                                                    RB4
20A     LNBCH.K=PLDRP.K/SLP.K                                                     RB5
6A      SLP.K=SLOPE                                      SLOPE OF THE BEACH       RB6
C       SLOPE=0.10                                                                RB7
58A     ATND1.K=TABHL(ATTND,LNBCH.K,0,1500,1500)                                  RB8
C       ATTND*=5000/0                                                             RB9
6A      ATND.K=ATND1.K           DAILY ATTEND. ADJ. BY RECREATION GRO. FAC.       RB10
51A     RATD1.K=CLIP(ATND.K,0,DAY.K,240)                                          RB11
51A     RATD2.K=CLIP(0,RATD1.K,DAY.K,350)                                         RB12
6R      RATD3.KL=RATD2.K                                                          RB13
1L      AREC.K=AREC.J+(DT)(RATD3.JK-RATD4.JK)  ACCUM DAILY REC ATTEND             RB14
51R     RATD4.KL=CLIP(AREC.K,0,DAY.K,364)                                         RB15
12A     RECB.K=(AREC.K)(VALRC.K)                                                  RB16
6A      VALRC.K=VALR                                                              RB17
C       VALR=1       VALUE OF RECREATION                                          RB18
51A     RCB.K=CLIP(RECB.K,0,DAY.K,364)                                            RB19
NOTE
NOTE    CALCULATION OF RECREATION COSTS
NOTE
C       INREC=187E4                                 TOTAL INITIAL REC. COSTS      RC1
6A      INRC1.K=INREC                                                             RC2
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13A    RCST.K=(3)(INRC1.K)(CRF50.K)                                         RC3
51A    ARCST.K=CLIP(RCST.K,0,DAY.K,364)                 ANN. REC. COSTS     RC4
NOTE
NOTE   STRUCTURE SIZES
NOTE
6A     CCAP.K=CHCAP                                     CHANNEL CAPACITY    SS1
12A    CCAPD.K=(CCAP.K)(86400)                                              SS2
C      CHCAP=21000                                                          SS3
6A     RCAP.K=RECAP                                                         SS4
C      RECAP=140000                                                         SS5
NOTE
NOTE   INITIAL CONDITIONS
NOTE
6N     RLVA=102300
6N     CLVA=15E6
6N     ACLVA=0
6N     APEC=0
6N     TIROT=0
NOTE
NOTE   NET BENEFIT
NOTE
10A    SUMBN.K=ADBR.K+AFLD1.K+AIB.K+FB.K+AWAQB.K+RCB.K                      NB1
10A    SUMCT.K=ADRCT.K+ARSCT.K+AIRCT.K+AFCST.K+ARCST.K+0                    NB2
7A     NETBN.K=SUMBN.K-SUMCT.K                          NET BENEFITS        NB3
6R     NETB1.KL=NETBN.K                                                     NB4
12R    NETB2.KL=(NETBN.K)(NETBN.K)                                          NB5
1L     SUNET.K=SUNET.J+(DT)(NETB1.JK+0)                SUM NET BENE.        NB6
1L     SSNET.K=SSNET.J+(DT)(NETB2.JK+0)                 SUM NET BEN. SQ.    NB7
20A    AVENB.K=SUNET.K/NOYRS.K                      AVE NET BENEFITS        NB8
49A    NOYRS.K=SWITCH(1,AJYRS.K,AJYRS.K)                                    NB9
7A     AJYRS.K=YEARS.K-1                                                    NB10
20A    AVVAR.K=SSQNT.K/NMNS1.K                        AVE VARIANCE OF NB    NB11
49A    NMNS1.K=SWITCH(1,YMNS1.K,YMNS1.K)                                    NB12
7A     YMNS1.K=YEARS.K-2                                                    NB13
7A     SSQNT.K=SSNET.K-SUMX2.K                                              NB14
44A    SUMX2.K=(SUNET.K)(SUNET.K)/NOYRS.K                                   NB15
30A    AVSTD.K=(1)SQRT(AVVAR.K)                  AVE STD DEV OF NET BENE    NB16
NOTE
NOTE   INITIAL CONDITIONS
NOTE
6N     SUNET=0
6N     SSNET=0
6N     NETB1=0
6N     NETB2=0
NOTE
NOTE          COSTS
NOTE
58A    IRCST.K=TABHL(IRC,RCAP,50000,225000,25000)    INITIAL RES COSTS      C1
C      IRC*=12E6/15467E3/165E5/19E6/23055E3/2767E4/3228E4/40E6              C2
13A    RSCT.K=(1.075)(IRCST.K)(CRF00.K)                                     C3
51A    ARSCT.K=CLIP(RSCT.K,0,DAY.K,364)            ANN. RESERVOIR COSTS     C4
13A    BCOIR.K=(1.075)(INIRC)(CRF00.K)                                      C5
51A    NITF1.K=CLIP(NIRTF.K,1,NIRTF.K,1)                                    C6
13A    IRRCT.K=(NITF1.K)(NIRTF.K)(BCOIR.K)                                  C7
C      INIRC=931300                                  INITIAL IRR COSTS      C8
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51A     AIRCT.K=CLIP(IRRCT.K,0,DAY.K,364)                   ANN. IRRIG. COSTS    C9
58A     IDRC.K=TABHL(IDRC1,CCAP.K,1000,21000,5000)    INITIAL  DRAIN COSTS    C10
C       IDRC1*=0/125000/16E5/4E6/8E5                                          C11
13A     DRCST.K=(1.1)(IDRC.K)(CRF00.K)                                        C12
51A     ADRCT.K=CLIP(DRCST.K,0,DAY.K,364)                     ANN. DRAIN COSTS  C13
NOTE
NOTE    CAPITAL RECOVERY FACTORS
NOTE
C       INTR=0.0325                 INTEREST RATE                             CR1
6A      INT1.K=INTR                                                           CR2
7A      INT2.K=1+INT1.K                                                       CR3
29A     INT3.K=(20)LOGN(INT2.K)                                  N=20YEARS    CR4
28A     INT4.K=(1)EXP(INT3.K)                                                 CR5
50A     CRF20.K=(INT1.K)(INT4.K)/(INT4.K-1)                 CRF FOR N=20      CR6
29A     INT5.K=(50)LOGN(INT2.K)                                  N=50YEARS    CR7
28A     INT6.K=(1)EXP(INT5.K)                                                 CR8
50A     CRF50.K=(INT1.K)(INT6.K)/(INT6.K-1)                 CRF FOR N=50      CR9
29A     INT7.K=(100)LOGN(INT2.K)                                 N=100YEARS   CR10
28A     INT8.K=(1)EXP(INT7.K)                                                 CR11
50A     CRF00.K=(INT1.K)(INT8.K)/(INT8.K-1)           CRF FOR N=100YEARS      CR12
NOTE
NOTE
NOTE    ANALYSIS OF STATIC ECONOMIC MODEL
NOTE
NOTE    MAXIMUM AND MINIMUM ANNUAL RESERVOIR LEVELS
NOTE
56A     MXRLV.K=MAX(RLVA.K,MXRL.JK)                     MAX. RES. LEVEL        E1
51R     MXRL.KL=CLIP(0,MXRLV.K,DAY.K,364)                                      E2
51A     MXRLC.K=CLIP(MXRLV.K,0,DAY.K,364)                  MAX. RES. COUNTER   E3
51R     RG900.KL=CLIP(1,0,MXRLC.K,R900.K)                                      E4
12A     R900.K=(0.90)(RCAP.K)                                                  E5
1L      RC900.K=RC900.J+(DT)(RG900.JK+0)  NO. TIMES GREATER THAN 0.90 RCAP     E6
51R     RG950.KL=CLIP(1,0,MXRLC.K,R950.K)                                      E7
12A     R950.K=(0.95)(RCAP.K)                                                  E8
1L      RC950.K=RC950.J+(DT)(RG950.JK+0)  NO. TIMES GREATER THAN .95 RCAP      E9
51R     RG980.KL=CLIP(1,0,MXRLC.K,R980.K)                                      E10
12A     R980.K=(0.98)(RCAP.K)                                                  E11
1L      RC980.K=RC980.J+(DT)(RG980.JK+0)  NO. TIMES GREATER THAN .98 RCAP      E12
51R     RG995.KL=CLIP(1,0,MXRLC.K,R995.K)                                      E13
12A     R995.K=(0.995)(RCAP.K)                                                 E14
1L      RC995.K=RC995.J+(DT)(RG995.JK+0)  NO. TIMES GREATER THAN .995 RCAP     E15
51R     RGCAP.KL=CLIP(1,0,MXRLC.K,RCAP.K)                                      E16
1L      RCCAP.K=RCCAP.J+(DT)(RGCAP.JK+0)   NO. TIMES GREATER THAN RES. CAP     E17
54A     MIRLV.K=MIN(RLVA.K,MINRL.JK)                    MIN. RES. CAP.         E18
51R     MINRL.KL=CLIP(RCAP.K,MIRLV.K,DAY.K,364)                                E19
51A     MIRLC.K=CLIP(MIRLV.K,0,DAY.K,364)                  MIN. RES. COUNTER   E20
51R     RG115.KL=CLIP(1,0,MIRLC.K,R115.K)                                      E21
12A     R115.K=(1.15)(MICVP.K)                                                 E22
1L      RC115.K=RC115.J+(DT)(RG115.JK+0) NO. TIMES GREATER THAN 1.15 MICVP     E23
51R     RG105.KL=CLIP(1,0,MIRLC.K,R105.K)                                      E24
12A     R105.K=(1.05)(MICVP.K)                                                 E25
1L      RC105.K=RC105.J+(DT)(RG105.JK+0) NO. TIMES GREATER THAN 1.05 MICVP     E26
51R     RG098.KL=CLIP(1,0,MIRLC.K,R098.K)                                      E27
12A     R098.K=(0.98)(MICVP)                                                   E28
1L      RC098.K=RC098.J+(DT)(RG098.JK+0) NO. TIMES GREATER THAN .98 MICVP      E29
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51R   RG090.KL=CLIP(1,0,MIRLC.K,R090.K)                                        E30
12A   R090.K=(0.90)(MICVP)                                                     E31
1L    RC090.K=RC090.J+(DT)(RG090.JK+0) NO. TIMES GREATER THAN .90 MICVP        E32
51R   RGCPL.KL=CLIP(1,0,MIRLC.K,MICVP.K)                                       E33
1L    RCCPL.K=RCCPL.J+(DT)(RGCPL.JK+0)   NO. TIMES GREATER THAN CONS. PL       E34
51A   PDTM.K=CLIP(PRDTM.K,0,DAY.K,364)                                         E35
51R   PD100.KL=CLIP(1,0,PDTM.K,1.0)              DRAINAGE TARGET COUNTER       E36
1L    DG100.K=DG100.J+(DT)(PD100.JK+0)   NO. TIMES EQUAL TO 1.0                E37
51R   PD90.KL=CLIP(1,0,PDTM.K,0.9)                                             E38
1L    DG90.K=DG90.J+(DT)(PD90.JK+0)                                            E39
51R   PD80.KL=CLIP(1,0,PDTM.K,0.8)                                             E40
1L    DG80.K=DG80.J+(DT)(PD80.JK+0)                                            E41
NOTE
NOTE  FLOOD LOSS DISTRIBUTION   MAXIMUM ACTUAL AND POTENTIAL FLOWS
NOTE
51A   MXACC.K=CLIP(MTIN.K,0,DAY.K,364)         MAX. ACTUAL INST.CHAN. FLOW     E42
51R   CAG11.KL=CLIP(1,0,MXACC.K,11000)                                         E43
1L    CAC11.K=CAC11.J+(DT)(CAG11.JK+0) NO. TIMES ACTUALLY ABOVE 11000CFS       E44
51R   CGC21.KL=CLIP(1,0,MXACC.K,21000)                                         E45
1L    CCC21.K=CCC21.J+(DT)(CGC21.JK+0)  NO. TIMES ACT. ABOVE 21000CFS          E46
51R   CAG16.KL=CLIP(1,0,MXACC.K,16000)                                         E47
1L    CAC16.K=CAC16.J+(DT)(CAG16.JK+0)                                         E48
51R   CAG20.KL=CLIP(1,0,MXACC.K,20000)                                         E49
1L    CAC20.K=CAC20.J+(DT)(CAG20.JK+0)                                         E50
51R   CAG25.KL=CLIP(1,0,MXACC.K,25000)                                         E51
1L    CAC25.K=CAC25.J+(DT)(CAG25.JK+0)                                         E52
51A   MXPCC.K=CLIP(MCLVA.K,0,DAY.K,364)     MAX.POTENTIAL CHAN. FLOW           E53
51R   CPG11.KL=CLIP(1,0,MXPCC.K,11000)                                         E54
1L    CPC11.K=CPC11.J+(DT)(CPG11.JK+0)                                         E55
51R   CPG21.KL=CLIP(1,0,MXPCC.K,21000)                                         E56
1L    CPC21.K=CPC21.J+(DT)(CPG21.JK+0)   NO. TIMES POTENTLY ABOVE 21000        E57
51R   CPG25.KL=CLIP(1,0,MXPCC.K,25000)                                         E58
1L    CPC25.K=CPC25.J+(DT)(CPG25.JK+0)                                         E59
51R   CPG16.KL=CLIP(1,0,MXPCC.K,16000)                                         E60
1L    CPC16.K=CPC16.J+(DT)(CPG16.JK+0)                                         E61
51R   CPG20.KL=CLIP(1,0,MXPCC.K,20000)                                         E62
1L    CPC20.K=CPC20.J+(DT)(CPG20.JK+0)                                         E63
NOTE
NOTE  IRRIGATION TARGET
NOTE
51A   PITM.K=CLIP(PERTM.K,0,DAY.K,364)                                         E64
51R   PI100.KL=CLIP(1,0,PITM.K,.999)                IRR. TARGET COUNTER        E65
1L    IG100.K=IG100.J+(DT)(PI100.JK+0)    NO. TIMES EQUAL TO 1.0               E66
51R   PI90.KL=CLIP(1,0,PITM.K,0.9)                                             E67
1L    IG90.K=IG90.J+(DT)(PI90.JK+0)                                            E68
51R   PI80.KL=CLIP(1,0,PITM.K,0.8)                                             E69
1L    IG80.K=IG80.J+(DT)(PI80.JK+0)                                            E70
NOTE
NOTE  MINIMUM CHANNEL FLOW AND CONSERVATION POOL
NOTE
51A   MIPCF.K=CLIP(MICLS.K,0,DAY.K,364)                                        E71
51R   PCF12.KL=CLIP(1,0,MIPCF.K,1.2)             FLOW TARGET COUNTER           E72
1L    CG120.K=CG120.J+(DT)(PCF12.JK+0)    NO. TIMES GR. THAN 1.20              E73
51R   PCF10.KL=CLIP(1,0,MIPCF.K,.999)                                          E74
1L    CG100.K=CG100.J+(DT)(PCF10.JK+0)                                         E75
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51R    PCF9.KL=CLIP(1.0,MIPCF.K,0.9)                                                E76
1L     CG90.K=CG90.J+(DT)(PCF9.JK+0)                                                E77
51R    PCF8.KL=CLIP(1.0,MIPCF.K,0.8)                                                E78
1L     CG80.K=CG80.J+(DT)(PCF8.JK+0)                                                E79
51R    PCP12.KL=CLIP(1.0,MIPCP.K,1.2)           POOL TARGET COUNTER                 E80
1L     PG120.K=PG120.J+(DT)(PCP12.JK+0)         NO. TIMES GR. THAN 1.2              E81
51R    PCP10.KL=CLIP(1.0,MIPCP.K,.999)                                              E82
1L     PG100.K=PG100.J+(DT)(PCP10.JK+0)                                             E83
51R    PCP9.KL=CLIP(1.0,MIPCP.K,0.9)                                                E84
1L     PG90.K=PG90.J+(DT)(PCP9.JK+0)                                                E85
51R    PCP8.KL=CLIP(1.0,MIPCP.K,0.8)                                                E86
1L     PG80.K=PG80.J+(DT)(PCP8.JK+0)                                                E87
NOTE
NOTE   WATER QUALITY TARGET
NOTE
51R    PW120.KL=CLIP(1.0,MIPWQ.K,1.2)           W.Q. TARGET COUNTER                 E88
1L     WG120.K=WG120.J+(DT)(PW120.JK+0)             NO. TIMES GR. THAN 1.2          E89
51R    PW100.KL=CLIP(1.0,MIPWQ.K,.999)                                              E90
1L     WG100.K=WG100.J+(DT)(PW100.JK+0)                                             E91
51R    PW90.KL=CLIP(1.0,MIPWQ.K,0.9)                                                E92
1L     WG90.K=WG90.J+(DT)(PW90.JK+0)                                                E93
51R    PW80.KL=CLIP(1.0,MIPWQ.K,0.8)                                                E94
1L     WG80.K=WG80.J+(DT)(PW80.JK+0)                                                E95
51R    PW50.KL=CLIP(1.0,MIPWQ.K,0.5)                                                E96
1L     WG50.K=WG50.J+(DT)(PW50.JK+0)                                                E97
NOTE
NOTE   RECREATION ATTENDANCE=REC. BEN. IF VALR=1
NOTE
51R    RAG45.KL=CLIP(1.0,RCB.K,450000)                                              E98
1L     RAC45.K=RAC45.J+(DT)(RAG45.JK+0)  NO. TIMES GR. THAN 450000                  E99
51R    RAG48.KL=CLIP(1.0,RCB.K,480000)                                              E100
1L     RAC48.K=RAC48.J+(DT)(RAG48.JK+0)                                             E101
51R    RAG50.KL=CLIP(1.0,RCB.K,500000)                                              E102
1L     RAC50.K=RAC50.J+(DT)(RAG50.JK+0)                                             E103
51R    RAG52.KL=CLIP(1.0,RCB.K,520000)                                              E104
1L     RAC52.K=RAC52.J+(DT)(RAG52.JK+0)                                             E105
51R    RAG55.KL=CLIP(1.0,RCB.K,550000)                                              E106
1L     RAC55.K=RAC55.J+(DT)(RAG55.JK+0)                                             E107
NOTE
NOTE   INITIAL CONDITIONS FOR ECON. ANALYSIS
NOTE
6N     MXRL=0
6N     RG900=0
6N     RC900=0
6N     RG950=0
6N     RC950=0
6N     RG980=0
6N     RC980=0
6N     RG995=0
6N     RC995=0
6N     RGCAP=0
6N     RCCAP=0
6N     MINRL=RECAP
6N     RC090=0
6N     RG090=0
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6N      RC098=0
6N      RG098=0
6N      RG105=0
6N      RC105=0
6N      RG115=0
6N      RC115=0
6N      RGCPL=0
6N      RCCPL=0
6N      PD100=0
6N      DG100=0
6N      PD90=0
6N      DG90=0
6N      PD80=0
6N      DG80=0
6N      CAG11=0
6N      CAC11=0
6N      CGC21=0
6N      CCC21=0
6N      CAG16=0
6N      CAC16=0
6N      CAG20=0
6N      CAC20=0
6N      CAG25=0
6N      CAC25=0
6N      CPG11=0
6N      CPC11=0
6N      CPG21=0
6N      CPC21=0
6N      CPG25=0
6N      CPC25=0
6N      CPG16=0
6N      CPC16=0
6N      CPG20=0
6N      CPC20=0
6N      PI100=0
6N      IG100=0
6N      PI90=0
6N      IG90=0
6N      PI80=0
6N      IG80=0
6N      PCF12=0
6N      CG120=0
6N      PCF10=0
6N      CG100=0
6N      PCF9=0
6N      CG90=0
6N      PCF8=0
6N      CG80=0
6N      PCP12=0
6N      PG120=0
6N      PCP10=0
6N      PG100=0
6N      PCP9=0
6N      PG90=0
6N      PCP8=0
```

```
6N      PG80=0
6N      PW120=0
6N      WG120=0
6N      PW100=0
6N      WG100=0
6N      PW90=0
6N      WG90=0
6N      PW80=0
6N      WG80=0
6N      PW50=0
6N      WG50=0
6N      RAG45=0
6N      RAC45=0
6N      RAG48=0
6N      RAC48=0
6N      RAG50=0
6N      RAC50=0
6N      RAG52=0
6N      RAC52=0
6N      RAG55=0
6N      RAC55=0
NOTE
NOTE
NOTE    SUM OF ANNUAL FLOWS
NOTE
6R      SFR11.KL=FRIN1.K                                                    FA1
1L      SFR12.K=SFR12.J+(DT)(SFR11.JK-A1FR1.JK)                             FA2
51A     ASFR1.K=CLIP(SFR12.K,0,DAY.K,364)  ANN. SUM FRIN1                   FA3
6R      A1FR1.KL=ASFR1.K                                                    FA4
6R      SFC21.KL=FCIN2.K                                                    FA5
1L      SFC22.K=SFC22.J+(DT)(SFC21.JK-A1FC2.JK)                             FA6
51A     ASFC2.K=CLIP(SFC22.K,0,DAY.K,364)             ANN. SUM FCIN2        FA7
6R      A1FC2.KL=ASFC2.K                                                    FA8
56A     MXLS1.K=MAX(MXFL1.JK,FXL1.K)      MAX SEASON 1 RES. LEVEL           FA9
51R     MXFL1.KL=CLIP(0,MXLS1.K,DAY.K,364)                                  FA10
51A     FXL1.K=CLIP(0,RLVA.K,DAY.K,92)                                      FA11
56A     MXLS2.K=MAX(MXFL2.JK,FXL2.K)      MAX SEASON2 RES. LEVEL            FA12
51R     MXFL2.KL=CLIP(0,MXLS2.K,DAY.K,364)                                  FA13
51A     FXL2.K=CLIP(0,RLVA.K,DAY.K,183)                                     FA14
56A     MXLS3.K=MAX(MXFL3.JK,FXL3.K)      MAX SEASON3  RES. LEVEL           FA15
51R     MXFL3.KL=CLIP(MXLS3.K,0,DAY.K,183)                                  FA16
51A     FXL3.K=CLIP(RLVA.K,0,DAY.K,183)                                     FA17
56A     MXLS4.K=MAX(MXFL4.JK,FXL4.K)      MAX SEASON4  RES. LEVEL           FA18
51R     MXFL4.KL=CLIP(MXLS4.K,0,DAY.K,274)                                  FA19
51A     FXL4.K=CLIP(RLVA.K,0,DAY.K,274)                                     FA20
NOTE
NOTE    INITIAL CONDITIONS  FOR FLOW ANALYSIS
NOTE
6N      SFR11=0
6N      SFR12=0
6N      A1FR1=0
6N      SFC21=0
6N      SFC22=0
6N      A1FC2=0
6N      MXFL1=0
```

```
6N      MXFL2=0
6N      MXFL3=0
6N      MXFL4=0
NOTE
NOTE    SPILL DATA
NOTE
21A     SP2.K=(1/43560)(ROUT5.K-MINXX.K)                                             SP1
51R     SP3.KL=CLIP(SP2.K,0,SP2.K,0)                                                 SP2
1L      SP4.K=SP4.J+(DT)(SP3.JK-SP5.JK)                      VOL. SPILL AC. FT.     SP3
51R     SP5.KL=CLIP(SP4.K,0,DAY.K,364)                                               SP4
51R     SPCTR.KL=CLIP(1,0,SP5.JK,1)                                                  SP5
1L      SPCTS.K=SPCTS.J+(DT)(SPCTR.JK+0)                        NO. YEARS SPILL     SP6
NOTE
NOTE    INTIAL CONDITIONS
NOTE
6N      SP3=0
6N      SP4=0
6N      SP5=0
6N      SPCTR=0
6N      SPCTS=0
NOTE
NOTE    MAX AND MIN DAILY FLOWS
NOTE
56A     MADR.K=MAX(MADRD.JK,FRIN1.K)                   MAX. AVE. DAILY RES.         DF1
51R     MADRD.KL=CLIP(0,MADR.K,DAY.K,364)                                            DF2
56A     MADC.K=MAX(MADCD.JK,FCIN2.K)                  MAX.AVE.DAILY CHAN.           DF3
51R     MADCD.KL=CLIP(0,MADC.K,DAY.K,364)                                            DF4
54A     MNR.K=MIN(MNR1.JK,FRIN1.K)                    MIN. AVE. DAILY RES.          DF5
51R     MNR1.KL=CLIP(1000,MNR.K,DAY.K,364)                                           DF6
54A     MNC.K=MIN(MNC1.JK,FCIN2.K)                         MIN AVE DAILY CHAN       DF7
51R     MNC1.KL=CLIP(1000,MNC.K,DAY.K,364)                                           DF8
6N      MADRD=0
6N      MADCD=0
6N      MNR1=1000
6N      MNC1=1000
NOTE
NOTE    FISH RELEASE
NOTE
51R     ADRF2.KL=CLIP(ADRF3.K,0,ADRF3.K,0)                                           FR1
7A      ADRF3.K=ADRF4.K-FRIN1.K                                                      FR2
51A     ADRF4.K=CLIP(FIRL1.K,RMFF1.K,DAY.K,241)                                      FR3
1L      ADRF1.K=ADRF1.J+(DT)(ADRF2.JK-TAFR.JK)  ACC. FISH REL.                       FR4
51R     TAFR.KL=CLIP(ADRF1.K,0,DAY.K,364)                                            FR5
NOTE
NOTE    SHORTAGE INDEX
NOTE
NOTE
NOTE    DRAINAGE SHORTAGE INDEX
NOTE
1L      SIDR.K=SIDR.J+(DT)(SIDR1.JK+0)                                               SI1
12A     SIDR1.K=(PDSH.K)(PDSH.K)                                                     SI2
51A     PDSH.K=CLIP(PDRSH.K,0,DAY.K,364)                                             SI3
20A     PDRSH.K=DRSH1.K/0.3                                                          SI4
51A     DRSH1.K=CLIP(DRSH.K,0,DRSH.K,0)                                              SI5
7A      DRSH.K=PRCLV.K-0.3                                                           SI6
```

```
1L      DRBL.K=DRBL.J+(DT)(DRBL1.JK+0)              DRAINAGE $ LOSS                SI7
12R     DRBL1.KL=(ATDRB.K)(PDTNM.K)                                                 SI8
51A     PDTNM.K=CLIP(PDTN1.K,0,DAY.K,364)                                           SI9
7A      PDTN1.K=1.0-PRDTM.K                                                         SI10
NOTE
NOTE    CHANNEL SHORTAGE INDEX
NOTE
20A     CHR.K=MIOFL.K/MTIN.K                                                        SI11
7A      CHR1.K=1-CHR.K                                                              SI12
56A     CHRM.K=MAX(CHR2.JK,CHR1.K)                                                  SI13
51R     CHR2.KL=CLIP(0,CHRM.K,DAY.K,364)                                            SI14
1L      SICH.K=SICH.J+(DT)(SICH1.JK+0)                                              SI15
12R     SICH1.KL=(PCHS.K)(PCHS.K)                                                   SI16
51A     PCHS.K=CLIP(CHRM.K,0,DAY.K,364)                                             SI17
6R      FDLR1.KL=FDLR.K  ANN. CHAN. FLOOD LOSS                                      SI18
1L      FDLR2.K=FDLR2.J+(DT)(FDLR1.JK+0)      FLOOD LOSS                            SI19
NOTE
NOTE    FLOOD STORAGE SHORTAGE INDEX
NOTE
1L      SIFS.K=SIFS.J+(DT)(SIFS1.JK+0)                                              SI20
12R     SIFS1.KL=(PRS.K)(PRS.K)                                                     SI21
51A     PRS.K=CLIP(PRS1.K,0,DAY.K,364)                                              SI22
56A     PRS1.K=MAX(PRS2.JK,PRS3.K)                                                  SI23
51R     PRS2.KL=CLIP(0,PRS1.K,DAY.K,364)                                            SI24
20A     PRS3.K=INSUF.K/FR3DT.K                                                      SI25
7R      WIRFL.KL=WLFB5.K-WILFB.K                                                    SI26
51A     WLFB5.K=CLIP(WLFB2.K,0,DAY.K,364)                                           SI27
1L      WRFL.K=WRFL.J+(DT)(WIRFL.JK+0)  W. R. FLOOD $ LOSS                          SI28
NOTE    IRRIGATION SHORTAGE INDEX
NOTE
1L      SIIR.K=SIIR.J+(DT)(SIIR1.JK+0)                                              SI29
12R     SIIR1.KL=(PIRS.K)(PIRS.K)                                                   SI30
51A     PIRS.K=CLIP(PIRS1.K,0,DAY.K,364)                                            SI31
51A     PIRS1.K=CLIP(PIRS2.K,0,PIRS2.K,0)                                           SI32
7A      PIRS2.K=1-PERTM.K                                                           SI33
1L      IRL.K=IRL.J+(DT)(IRL1.JK+0)  IRRIG. $ LOSS                                  SI34
7R      IRL1.KL=AIB1.K-AIB.K                                                        SI35
51A     AIB1.K=CLIP(ANIB.K,0,DAY.K,364)                                             SI36
NOTE
NOTE    FISH SHORTAGE INDEX
NOTE
1L      SIFD.K=SIFD.J+(DT)(SIFD1.JK+0)    SI FISH DEMAND (DNSTR. RELEASE)          SI37
12R     SIFD1.KL=(PFSD.K)(PFSD.K)                                                   SI38
51A     PFSD.K=CLIP(PFSD1.K,0,DAY.K,364)                                            SI39
51A     PFSD1.K=CLIP(PFSD2.K,0,PFSD2.K,.001)                                        SI40
40A     PFSD2.K=1+(1/FIDMD.K)(-FIRLS.K-130)                                         SI41
1L      SIFR.K=SIFR.J+(DT)(SIFR1.JK+0)                 SI FISH RESERVOIR            SI42
12R     SIFR1.KL=(PFSR.K)(PFSR.K)                                                   SI43
51A     PFSR.K=CLIP(PFSR1.K,0,DAY.K,364)                                            SI44
51A     PFSR1.K=CLIP(PFSR2.K,0,PFSR2.K,0)                                           SI45
7A      PFSR2.K=1-MIRL.K                                                            SI46
1L      FADL.K=FADL.J+(DT)(FADL1.JK+0)  FISH ANAD. $ LOSS CHAN. AND RES.            SI47
51R     FADL1.KL=CLIP(FADL2.K,0,FADL2.K,0)                                          SI48
7A      FADL2.K=FADB.K-FIBAD.K                                                      SI49
51A     FADB.K=CLIP(ADFB.K,0,DAY.K,364)                                             SI50
```

```
1L     FADC.K=FADC.J+(DT)(FADC1.JK+0)  ANAD. $ LOSS CHAN. ONLY          SI51
51R    FADC1.KL=CLIP(FADC2.K,0,DAY.K,364)                               SI52
12A    FADC2.K=(PACL.K)(ADFB.K)                                         SI53
51A    PACL.K=CLIP(PACL1.K,0,PACL1.K,0)                                 SI54
7A     PACL1.K=1-PACT.K                                                 SI55
58A    PACT.K=TABHL(PFIB1,MICLS.K,0,1.2,0.2)                            SI56
1L     FADS.K=FADS.J+(DT)(FADS1.JK+0)  ANAD. $ LOSS RES. ONLY           SI57
51R    FADS1.KL=CLIP(FADS2.K,0,DAY.K,364)                               SI58
12A    FADS2.K=(PASL.K)(ADFL.K)                                         SI59
51A    PASL.K=CLIP(PASL1.K,0,PASL1.K,0)                                 SI60
7A     PASL1.K=1-PAST.K                                                 SI61
58A    PAST.K=TABHL(PFIB1,MIRL.K,0,1.2,0.2)                             SI62
1L     FRS.K=FRS.J+(DT)(FRS1.JK+0)      RES SPORT FISH $ LOSS           SI63
12R    FRS1.KL=(PRSFL.K)(RSFB.K)                                        SI64
51A    PRSFL.K=CLIP(PRFL2.K,0,DAY.K,364)                                SI65
51A    PRFL2.K=CLIP(PRFL1.K,0,PRFL1.K,0)                                SI66
7A     PRFL1.K=1-PFERS.K                                                SI67
NOTE
NOTE   WATER QUALITY SHORTAGE INDEX
NOTE
1L     SIWQ.K=SIWQ.J+(DT)(SIWQ1.JK+0)                                   SI68
12R    SIWQ1.KL=(PSWQ.K)(PSWQ.K)                                        SI69
51A    PSWQ.K=CLIP(PSWQ1.K,0,DAY.K,364)                                 SI70
49A    PSWQ1.K=SWITCH(0,PSWQ2.K,WQDD.K)                                 SI71
40A    PSWQ2.K=1+(1/DMD1.K)(-DMD1.K+FTMD.K)                             SI72
49A    DMD1.K=SWITCH(1,WQDD.K,WQDD.K)                                   SI73
56A    WQDD.K=MAX(WQDD1.JK,WQDD2.K)                                     SI74
7A     WQDD2.K=WQDCT.K+RWQDT.K                                          SI75
51R    WQDD1.KL=CLIP(0,WQDD.K,DAY.K,364)                                SI76
1L     FTMD.K=FTMD.J+(DT)(SFTMD.JK-TFTMD.JK)                            SI77
51R    SFTMD.KL=CLIP(WRFS.K,0,WRFS.K,0)                                 SI78
7A     WRFS.K=WQOBJ.K-TFWIN.K                                           SI79
51R    TFTMD.KL=CLIP(FTMD.K,0,1,DAY.K)                                  SI80
1L     TWQRL.K=TWQRL.J+(DT)(WQRL2.JK-AWQRL.JK)                          SI81
51R    AWQRL.KL=CLIP(TWQRL.K,0,1,DAY.K)                                 SI82
6R     WQRL2.KL=WQRL1.K                                                 SI83
1L     WQL.K=WQL.J+(DT)(WQL1.JK+0)                                      SI84
12R    WQL1.KL=(PWQL.K)(WQBN.K)                                         SI85
51A    PWQL.K=CLIP(PWQL1.K,0,DAY.K,364)                                 SI86
7A     PWQL1.K=1-PWQS.K                                                 SI87
NOTE
NOTE   RECREATION SHORTAGE INDEX
NOTE
3L     ARLVA.K=ARLVA.J+(DT)(1/DDK.J)(ARLV.JK-TARLV.JK)                  SI88
51R    TARLV.KL=CLIP(ARLVA.K,0,DAY.K,364)                               SI89
51R    ARLV.KL=CLIP(RLV.K,0,DAY.K,240)                                  SI90
51A    RLV.K=CLIP(0,RLVA.K,DAY.K,350)                                   SI91
51A    DDK.K=CLIP(1,110,DAY.K,351)                                      SI92
1L     SIRL.K=SIRL.J+(DT)(SIRL1.JK+0)                                   SI93
12R    SIRL1.KL=(PSRL.K)(PSRL.K)                                        SI94
51A    PSRL.K=CLIP(PSRL1.K,0,DAY.K,364)                                 SI95
27A    PSRL1.K=(-ARLVA.K/RCAP.K)+1                                      SI96
1L     RECL.K=RECL.J+(DT)(RECL1.JK+0)  RECREATION $ LOSS                SI97
51R    RECL1.KL=CLIP(RECL2.K,0,DAY.K,364)                               SI98
7A     RECL2.K=550000-AREC.K                                            SI99
```

```
6N      ADRF1=0
6N      ADRF2=0
6N      TAFR=0
6N      SIDR=0
6N      DRBL=0
6N      DRBL1=0
6N      CHR2=0
6N      SICH=0
6N      SICH1=0
6N      FDLR1=0
6N      FDLR2=0
6N      SIFS=0
6N      SIFS1=0
6N      PRS2=0
6N      WIRFL=0
6N      WRFL=0
6N      SIFD=0
6N      SIFD1=0
6N      SIFR=0
6N      SIFR1=0
6N      FADL=0
6N      FADL1=0
6N      FADC=0
6N      FADC1=0
6N      FADS=0
6N      FADS1=0
6N      FRS=0
6N      FRS1=0
6N      SIWG=0
6N      SIWG1=0
6N      WQDD1=0
6N      TFTMD=0
6N      SFTMD=0
6N      WQRL2=0
6N      AWQRL=0
6N      WQL=0
6N      WQL1=0
6N      ARLVA=0
6N      TARLV=0
6N      ARLV=0
6N      SIRL=0
6N      SIRL1=0
6N      RECL=0
6N      RECL1=0
6N      FTMD=0
6N      TWQRL=0
6N      SIIR=0
6N      SIIR1=0
6N      IRL=0
6N      IRL1=0
NOTE
NOTE    NEW PRINT CARD FOR 50 YEAR SIMULATION 7/17/68
NOTE
PRINT 1)YEARS,SUM3,CURN,ASFR1,ASFC2,MXRLC,RC900,RC950,RC980,RC995/2)RCCA
X1      P,MIRLC,RC115,RC105,RCCPL,RC098,RC090,PRCLV,PUTM,ADSR/3)DG100,DG90
```

```
X2     ,DG80,MXACC,FLDLP,MCLVA,FDLAR,AFLD1,CAC11,CAC16/4)CAC20,CCC21,CAC2
X3     5,CPC11,CPC16,CPC20,CPC21,CPC25,NIRGT,TIRO/5)PITH,ANIDH,IG100,IG90
X4     ,IG80,MIPCF,CG120,CG100,CG90,CG80/6)MIPCP,PG120,PG100,PG90,PG80,PF
X5     BRS,FIBRS,PFDAD,FIDAD,FD/7)MIFWR,PWQB,WAQB,MIPWG,WG120,WG100,WG90,
X6     WG80,WG50,AREC/8)RCB,RAC45,RAC48,RAC50,RAC52,RAC55,SP4,SPCTS,SUMBN
X7     ,SUMCT/9)NETBN,SUNET,SSNET,MADR,MNR,MADC,MNC,BRSI2,DAMRL,DAM3D/10)
X8     MXLB1,MXLB2,MXLB3,MXLB4,ADRF1,SIDR,DRDL,SICH,FDLR2,SIFS
PRINT 11)WRFL,SIIR,IRL,SIFD,SIFR,FADL,FADC,FADS,SIWG,WGL/12)TWGRL,SIRL,R
X1     BCL,AVENB,AVVAR,AVSTD,DMR3B,FRS,DA4IR,RLVA
SPEC   DT=1/LENGTH=18930/PRTPER=364/PLTPER=0
```

DYNAMO HYDROLOGIC SIMULATION AND ANALYSIS

The primary purpose of the hydrologic simulator was to develop flows for a period of time greater than the number of years of historical records. This hydrologic simulator is identical to the one outlined in the previous DYNAMO program, except for the two additions. The maximum and minimum avaerage monthly historical flows for the downstream station are added to the input data (minimum downstream = minimum upstream). These additions are used later in the flow analysis section.

Before the hydrologic simulator could be used in the previous DYNAMO program, the simulated flows had to be analyzed and compared to the historical records by use of important parameters. These parameters, found for both stations for each year simulated, were as follows:

1. Annual sum of flows
2. Maximum daily flow
3. Minimum daily flow
4. Maximum instantaneous flow
5. Maximum consecutive 3-day flow
6. Minimum consecutive 7-day flow
7. Minimum consecutive 120-day flow
8. Frequency of flows occurring below the average monthly historical minimum
9. Frequency of simulated flows occurring above the absolute maximum historical flow
10. Frequency of simulated flows greater than:
    a) maximum average daily flow
    b) maximum instantaneous flow
    c) monthly average maximum flow
11. Maximum average simulated flow for each season
12. Minimum average simulated flow for each season

The Willamette River hydrology section is identical to the one used in the previously outlined DYNAMO program. Following this is an analysis section which determines the number of years that the sum of the spring inflow is less than 66,500, 51,000, and 30,000 acre feet. This is done to aid in water quality design decisions.

EXPLANATION OF FORTRAN HYDROLOGIC SIMULATION AND ANALYSIS

A flow diagram for the FORTRAN hydrologic simulator would be identical to the flow diagram for the DYNAMO hydrologic simulator. The FORTRAN flow analysis section is similar to the DYNAMO flow analysis except some additional hydrologic parameters are measured. The yearly parameters found are (for both upstream and downstream stations):

1. Yearly mean flow
2. Yearly standard deviation
3. Largest daily flow
4. Maximum average three-consecutive day flow
5. Maximum average ten-consecutive day flow
6. Minimum daily flow
7. Minimum average seven-consecutive day flow
8. Minimum average thirty-consecutive day flow
9. Minimum average 120-consecutive day flow

```
KERRI4,7,2000,350000.803278,KIP
.
.**************************************
.
.                RETURN TO
.          SACRAMENTO STATE COLLEGE
.
.
.**************************************
.
RUN(S,,,,,,163840)
KERRI4.
EXIT.
DMP.
'
      PROGRAM KERRI4(INPUT,OUTPUT,TAPE6=OUTPUT)
      DIMENSION AX(367),SX(367),GX(367),DX(365),B(4)
      DIMENSION BB(9,365),AS(3,365),SS(3,365),GS(3,365),AL(3,365)
      DIMENSION NO(3),XC(3,366),Q(3,367)
      DIMENSION S(3,366),G(3,367),PC(6,366),PP(6,365),E(3,367),F(3,367)
      DIMENSION DA(365),N(3),A(4,5)
      DIMENSION QX(100,2,366),GK(2,366)
      DIMENSION NYX(100)
      DIMENSION BIG(2,100),SMALL(2,100),SUM3(2),SUM3S(2,100),SUM7(2)
      DIMENSION SUM7S(2,100),SU10(2),SU10S(2,100),SU30(2),SU30S(2,100)
      DIMENSION S120(2),S120S(2,100),AR(100),SXK(2,100),SX2(2,100)
      ICOMB=0
      CAY = 1.
      NS=2
      NY=50
      LP=NY
      NP=5
      AAU=0
      JC =0
      JA =0
      CX =0
      LX=0
      N(1) = 19
      N(2) = 47
      N(3) = 50
      KILLPT=1.
      NSIM=0
C
C     READ STATMENT FOR THE HYDROLOGY PLOTTER
C
      READ 250,NXX,NIH,NIA,NZZ
 250  FORMAT(4A1)
      DO 10 L=1,NS
      LA=L+1
      LXR=LX
C
C     READS STATISTICAL ANALYSIS AND SMOOTHES     TO CARD 10
C
      DO 97 M=2,366
      READ 7,NO(L),AX(M),SX(M),GX(M)
```

```
  7   FORMAT (I5,10X,8F7.3)
      AX(M) = AX(M) *.43429
      SX(M) = SX(M) * .43429
 97   CONTINUE
      DO 6 M=2,366
      READ 7,NO(L),DX(M-1),(B(L2),L2=1,LA)
      DO 6 L2=1,LA
      LX=LXR+L2
6     BB(LX,M-1)=B(L2)
      AX(1)=AX(366)
      AX(367)=AX(2)
      SX(1)=SX(366)
      SX(367)=SX(2)
       GX(1)=GX(366)
      GX(367)=GX(2)
      DO 10 M=2,366
      AS(L,M-1)=(.84*AX(M)+.08*(AX(M-1)+AX(M+1)))*    2.3026
      SST=.5*SX(M)*SX(M)+.25*(SX(M-1)*SX(M-1)+SX(M+1)*SX(M+1))
      SS(L,M-1) = SQRTF(SST) * 2.3026
      GS(L,M-1)=.3*GX(M)+.15*(GX(M-1)+GX(M+1))
      AL(L,M-1)=SQRTF(1.-DX(M-1))
10    CONTINUE
      LPA=LP+2
C
C     SIMULATION SECTION   CARDS 101 TO 334
C
101   IF (CX)15,15,16
15    DO 30 L=1,NS
30    XC(L,1)=0.
      CX =1.
16    JA = JA + 1
      DO 35 M=1,365
      LX=0
      RAN = CAY
      CAY =0.
      DO 66 I = 1,12
66    CAY = CAY + RGEN(1.)
      CAY = CAY - 6.
      DO 35 L=1,NS
      LB=L-1
      IF(2-L)201,201,202
 202  XC(L,M+1)=BB(LX+2,M)*XC(L,M)+AL(L,M)*CAY
      GO TO 203
 201  XC(L,M+1)=BB(LX+2,M)*XC(L,M)+AL(L,M)*RAN
 203  CONTINUE
      LX=LX+2
      IF (L-1) 37,37,38
38    DO 3  L2=1,LB
      LX=LX+1
      XC(L,M+1)=XC(L,M+1)+BB(LX,M)*XC(L2,M+1)
 3    CONTINUE
37    IF(GS(L,M))320,321,32
321   GT=XC(L,M+1)
      GO TO 337
320   GST=GS(L,M)*.166667
```

```
      QTT=GST*(XC(L,M+1)-GST)+1.
      QT=(QTT*QTT*QTT-1.)/(3.*GST)
      PLIM=-2./GS(L,M)
      IF(GS(L,M))333,337,335
333   IF(QT-PLIM)337,337,334
334   QT=PLIM
      GO TO 337
335   IF(QT-PLIM)334,337,337
337   IF(L-2) 14,13,13
13    IF ( QT ) 1100,1101,1101
1100  Q(L,M)=EXPF(AS(L,M)+((QT*SS(L,M))/1.45))
      GO TO 336
1101  Q(L,M)=EXPF(AS(L,M)+((QT*SS(L,M))/1.2))
      GO TO 336
14    IF ( QT ) 1102,1103,1103
1102  Q(L,M)=EXPF(AS(L,M)+((QT*SS(L,M))/1.35))
      GO TO 336
1103  Q(L,M)=EXPF(AS(L,M)+((QT*SS(L,M))/1.1))
336   IF (M-365)35,27,27
 27   XC(L,1)=XC(L,366)
35    CONTINUE
      IYR = JA - 2
      IF (IYR) 16, 16, 42
   42 DO 43 L=1,NS
      DO 43 M=1,365
   43 QX(IYR,L,M)=Q(L,M)
      IF(IYR-NY) 101,602,602
C
C      HYDROLOGY PLOTTER  TO CARD 450
C
  602 IF(KILLPT) 600,600,601
 600  CA=15.
      DO 251 K=1,100
      NYX(K)=NXX
 251  CONTINUE
      DO 450 M=1,365
      HOL=Q(1,M)
      ALS=Q(2,M)
      CA=CA+1.
      IF(Q(1,M)-Q(2,M))460,460,461
 461  UU=HOL
      GO TO 462
 460  UU=ALS
 462  IF(UU-100.)463,463,464
 464  CONTINUE
 466  IF(UU-10000.)467,467,468
 468  IF(UU-100000.)469,469,479
 463  HH=HOL+.5
      NH=HH
      AA=ALS+.5
      NA=AA
      GO TO 470
 465  HH=HOL/10.+.5
      NH=HH
      AA=ALS/10.+.5
      NA=AA
      GO TO 470
 467  HH=HCL/100.+.5
      NH=HH
      AA=ALB/100.+.5
      NA=AA
      GO TO 470
 469  HH=HCL/1000.+.5
      NH=HH
      AA=ALB/1000.+.5
      NA=AA
      GO TO 470
 470  IF(NH-1)420,421,422
 420  NH=NH+1
 421  NH=NH+1
 422  IF(NA-1)423,424,425
 423  NA=NA+1
 424  NA=NA+1
 425  LH=NH-1
      LA=NA-1
      IF(CA-15.)471,472,472
 472  CA=0
      WRITE (6,473)
 473  FORMAT(25HYEAR DAY  HOLLEY ALBANY ,,49X,1H.,49X,1H.)
 471  IF(NA-NH)480,481,482
 481  WRITE (6,490) IYR,M,Q(1,M),Q(2,M),(NYX(I),I=1,LH),N22
 490  FORMAT(I3,2X,I3,2F8.0,1H.,100A1)
      GO TO 449
 480  NIP=NH-NA
      NOP=NIP-1
      IF(NOP)451,451,452
 452  WRITE (6,490) IYR,M,Q(1,M),Q(2,M),(NYX(I),I=1,LA),NIA,(NYX(I),I=1,
     1NOP),NIH
      GO TO 449
 451  WRITE (6,490) IYR,M,Q(1,M),Q(2,M),(NYX(I),I=1,LA),NIA,NIH
      GO TO 449
 482  NIP=NA-NH
      NOP=NIP-1
      IF(NOP)493,493,483
 483  WRITE (6,490) IYR,M,Q(1,M),Q(2,M),(NYX(I),I=1,LH),NIH,(NYX(I),I=1,
     1NOP),NIA
      GO TO 449
 493  WRITE (6,490) IYR,M,Q(1,M),Q(2,M),(NYX(I),I=1,LH),NIH,NIA
      GO TO 449
 479  WRITE (6,495) IYR,M,Q(1,M),Q(2,M)
 495  FORMAT(I3,2X,I3,2F8.0,15H.RANGE EXCEEDED)
      GO TO 449
 449  CONTINUE
 450  CONTINUE
C
C     BEGINNING OF ANALYSIS SECTION
C
      DO 17 L=1,NS
      DO 166 J=1,365
      Q(L,367-J)=Q(L,366-J)
 166   CONTINUE
17     CONTINUE
       NYS=NY-1
       AN=NYS
       BN=AN-1.
       CN=(AN+1.)/(AN-1.)
       DO 11 L=1,NS
 11    Q(L,367)=Q(L,366)
       IF(AAU)12,12,5
 12    AAU=1.
       NYC=0
 504   LX=0
       DO 51 L=1,NS
       LXR=LX
       DO 52 M=1,366
       S(L,M)=0
       G(L,M)=0
       DO 52 L2=1,L
       LX=LXR+L2
52     PC(LX,M)=0.
       DO 51 M=1,365
       DO8 L2=1,L
       LX=LXR+L2
8      PP(LX,M)=0.
51     CONTINUE
       IF(IBOMB)505,505,5
 505   GO TO 101
5      LX=0
       NYC=NYC+1
       DO 22 L=1,NS
 22    Q(L,1)=Q(L,367)
       DO 53 L=1,NS
       LXR=LX
       DO 54 M=1,366
       IF(IBOMB)511,511,512
 512   Q(L,M)=QX(NYC,L,M)
       Q(L,M)=(Q(L,M)-E(L,M))/F(L,M)
       FG=.5*GK(L,M)*Q(L,M)+1.
       Q(L,M)=6./GK(L,M)*(SIGNF(ABSF(FG)**.33333,FG)-1.)
       GO TO 513
 511   Q(L,M)=LOGF(Q(L,M))
       QX(NYC,L,M)=Q(L,M)
 513   S(L,M)=S(L,M)+Q(L,M)
       G(L,M)=G(L,M)+Q(L,M)*Q(L,M)*Q(L,M)
       DO 54 L2=1,L
       LX=LXR+L2
54     PC(LX,M)=PC(LX,M)+Q(L,M)*Q(L2,M)
       DO 18 M=1,365
       DO18 L2=1,L
       LX=LXR+L2
18     PP(LX,M)=PP(LX,M)+Q(L,M)*Q(L2,M+1)
       IF(IBOMB)514,514,53
 514   Q(L,367)=EXPF(Q(L,366))
 53    CONTINUE
       IF(NY-NYC)56,56,55
 55    IF(ISOMB)520,520,5
 520   GO TO 101
56     LX=0
       DO 26 L=1,NS
       LXR=LX
       DO 28 M=1,366
       E(L,M)=S(L,M)/(AN+1.)
       DO 23 L2=1,L
       LX=LXR+L2
       GT=G(L,M)-E(L,M)*(3.*PC(LX,M)-2.*E(L,M)*S(L,M))
23     PC(LX,M) =PC(LX,M)-E(L,M)*S(L2,M)
       F(L,M)=SQRTF(PC(LX,M)/AN)
 28    GK(L,M)=(CN*GT)/(F(L,M)*PC(LX,M))
       DO 25 M=1,365
       DO 25 L2=1,L
       LX=LXR+L2
25     PP(LX,M)=PP(LX,M)-E(L,M)*S(L2,M+1)
26     CONTINUE
       IF(ISOMB)500,500,501
 500   ISOMB=1
       WRITE(6,502)
 502   FORMAT(26HPROPERTIES OF LOG OF FLOWS,10X,28HMEAN STANDARD DEVIATIO
      1N SKEW//)
       DO 503 L=1,NS
       DO 503 M=2,366
       MC=M-1
       WRITE (6,1) N(L),MC,E(L,M),F(L,M),GK(L,M)
 503   CONTINUE
       NYC=0
       GO TO 504
 501   WRITE(6,506)
 506   FORMAT(60HPROPERTIES OF LOG NORMAL DEVIATES STATION DAY RSQUARED B
      1ETAS//)
C
C      START OF MATRIX INVERSION
C
       AA=0
       KX = (-1)
       DO 50 K=1,NS
       KA = K + 1
       KAA = K + 2
       KXR = KX - 1
       DO 57 M=2,366
       DO 58 J=3,KAA
       KX = KXR + J
       A(1,J) = 0
58     A(2,J)=PP(KX,M-1)
       A(1,1) = 1
       A(1,2) = 0
       A(2,2) = PC(KX,M-1)
       KX = 0
       IF (K-1)60,60,59
59     DO 61 J=3,KA
       DO 61 I=3,J
       KX = KX + 1
```

```
61      A(I,J)=PC(KX,M)
        DO 41  I = 3,KA
        KX = KX + 1
41      A(I,KAA) = PC(KX,M)
60      DO 62 ID=1,K
        IDA = ID + 1
        DO 63 I=IDA,KA
63      A(I,ID)=A(ID,I)
        DO 48  J = IDA, KAA
48      A(ID,J) = A(ID,J) / A(ID,ID)
        DO 62I=IDA,KA
        DO 62 J=I,KAA
62      A(I,J)=A(I,J) - A(I,ID)*A(ID,J)
        B(KA) = A(KA,KAA) / A(KA,KA)
        I = K
73      IA = I + 1
        B(I) = A(I,KAA)
        DO 71 J= IA,KA
71      B(I) = B(I)-B(J)*A(I,J)
        I = I - 1
        IF (I)77,77,73
77      D=B(2)*PP(KX+1,M-1)
        B(2) = B(2) * F(K,M-1) / F(K,M)
        IF (K-1)79,79,80
80      DO 81 J=3,KA
        KX = KXR + J
        D = D + B(J) * PC(KX,M)
81      B(J) = B(J) * F(J-2, M) / F(K,M)
79      D = D / PC(KX+1, M)
        MO = M-1
        WRITE (6,1) N(K),MO,D,(B(J),J=1,KA)
      1 FORMAT (I5,I7,3X,8F7.3)
57      CONTINUE
50      CONTINUE
C
C       THIS IS THE FLOW TESTING SECTION     TO CARD 180
C
 601    MX=0
        NSIM=NSIM+1
        LX=0
        JA =0
        JC = JC + 1
        IAC=1
        ND=365
        SND=ND
        MB1=0
        MB3=0
        MB10=0
        MS1=0
        MS7=0
        MS30=0
        MS120=0
C
C       TO INITIALIZE MAX AND MIN VARIABLES
C
```

```
      DO 401 IYR=1,NY
      DO 401 L=1,NS
      SXK(L,IYR)=0
      SX2(L,IYR)=0
      BIG(L,IYR)=0
      SUM3B(L,IYR)=0
      SU10B(L,IYR)=0
      SMALL(L,IYR)=1000.
      SUM7S(L,IYR)=1000.
      SU30S(L,IYR)=1000.
      S120S(L,IYR)=1000.
  401 CONTINUE
C
C     TO INITIALIZE SUMMING VARIABLES
C
      DO 400 L=1,NS
      SUM7(L)=0
      SU10(L)=0
      SU30(L)=0
      S120(L)=0
  400 CONTINUE
      DO 300 IYR=1,NY
      DO 300 L=1,NS
      DO 138 M=1, ND
      G(L,M)=GX(IYR,L,M)
      SXK(L,IYR)=SXK(L,IYR)+G(L,M)
      SX2(L,IYR)=SX2(L,IYR)+G(L,M)*G(L,M)
      SB=G(L,M)-BIG(L,IYR)
      IF(SB)107,107,108
  108 BIG(L,IYR)=G(L,M)
      MB1=M
  107 SML=G(L,M)-SMALL(L,IYR)
      IF(SML)111,111,109
  111 SMALL(L,IYR)=G(L,M)
      MS1=M
  109 IF(M-3)138,113,113
  113 SUM3(L)=(G(L,M)+G(L,M-1)+G(L,M-2))/3.
      IF(SUM3(L)-SUM3B(L,IYR))114,114,115
  115 SUM3B(L,IYR)=SUM3(L)
      MB3=M-2
  114 IF(M-7)138,119,119
  119 M=M+1
      DO 120 K=1,7
      JO=M-K
  120 SUM7(L)=SUM7(L)+G(L,JO)
      M=M-1
      SUM7(L)=SUM7(L)/7.
      IF(SUM7(L)-SUM7S(L,IYR))123,124,124
  123 SUM7S(L,IYR)=SUM7(L)
      MS7=M-6
  124 IF(M-10)138,125,125
  125 M=M+1
      DO 126 K=1,10
      JO=M-K
  126 SU10(L)=SU10(L)+G(L,JO)
```

```
      M=M-1
      SU10(L)=SU10(L)/10.
      IF(SU10(L)-SU10B(L,IYR))127,127,128
 128  SU10B(L,IYR)=SU10(L)
      MB10=M-9
 127  CONTINUE
      IF(M-30)138,130,130
 130  M=M+1
      DO 131 K=1,30
      JO=M-K
      SU30(L)=SU30(L)+Q(L,JO)
 131  CONTINUE
      M=M-1
      SU30(L)=SU30(L)/30.
      IF(SU30(L)-SU30S(L,IYR))132,133,133
 132  SU30S(L,IYR)=SU30(L)
      MS30=M-29
 133  CONTINUE
      IF(M-120)138,135,135
 135  M=M+1
      DO 136 K=1,120
      JO=M-K
 136  S120(L)=S120(L)+Q(L,JO)
      M=M-1
      S120(L)=S120(L)/120.
      IF(S120(L)-S120S(L,IYR))137,138,138
 137  S120S(L,IYR)=S120(L)
      MS120=M-119
 138  CONTINUE
      SX2(L,IYR)=SQRTF((SX2(L,IYR)-SXK(L,IYR)*SXK(L,IYR)/SND)/(SND-1.))
      SXK(L,IYR)=SXK(L,IYR)/SND
      WRITE (6,139) IYR,N(L)
 139  FORMAT(//11HTHE YEAR IS,I7,5X,14HTHE STATION IS,I5/)
      WRITE (6,149) SXK(L,IYR)
 149  FORMAT(20HTHE YEARLY MEAN IS   ,F10.1)
      WRITE (6,145) SX2(L,IYR)
 145  FORMAT(23HTHE YEARLY STD DEV IS   ,F10.1)
      WRITE (6,140) BIG(L,IYR),MB1
 140  FORMAT(16HLARGEST ONE DAY ,F6.0,16H  DAY BEGINNING ,I5/)
      WRITE (6,141) SUM3B(L,IYR), MB3
 141  FORMAT(25HLARGEST MEAN THREE DAYS  ,F6.0,16H  DAY BEGINNING ,I5/)
      WRITE (6,142) SU10B(L,IYR),MB10
 142  FORMAT(23HLARGEST MEAN TEN DAYS  ,F6.0,16H  DAY BEGINNING ,I5/)
      WRITE (6,143) SMALL(L,IYR),MS1
 143  FORMAT(16HSMALLEST ONE DAY,F6.0,16H  DAY BEGINNING ,I5/)
      WRITE (6,144) SUM7S(L,IYR),MS7
 144  FORMAT(25HSMALLEST MEAN SEVEN DAYS ,F7.1,16H  DAY BEGINNING ,I5/)
      WRITE (6,146) SU30S(L,IYR),MS30
 146  FORMAT(26HSMALLEST MEAN THIRTY DAYS ,F7.1,16H  DAY BEGINNING ,I5/)
      WRITE (6,147) S120S(L,IYR),MS120
 147  FORMAT(23HSMALLEST MEAN 120 DAYS ,F7.1,16H  DAY BEGINNING ,I5/)
 300  CONTINUE
C
C     TO RANK MAX AND MIN VARIABLES
C
```

```
      DO 180 L=1,NS
      WRITE (6,168) N(L)
168   FORMAT(//14HTHE STATION IS,I5//)
169   CONTINUE
      DO 181 K=1,NY
      GO TO(170,171,172,173,174,175,176,177,178,179),IAC
170   AR(K)=BIG(L,K)
      IF(1-K)198,182,182
182   CONTINUE
      WRITE (6,150)
150   FORMAT(16HLARGEST MEAN DAY/)
      GO TO 198
171   AR(K)=SUM3B(L,K)
      IF(1-K)198,189,189
189   CONTINUE
      WRITE (6,151)
151   FORMAT(23HLARGEST MEAN THREE DAYS/)
      GO TO 198
172   AR(K)=SU10B(L,K)
      IF(1-K)198,190,190
190   CONTINUE
      WRITE (6,152)
152   FORMAT (21HLARGEST MEAN TEN DAYS/)
      GO TO 198
173   AR(K)=SMALL(L,K)
      IF(1-K)198,183,183
183   CONTINUE
      WRITE(6,153)
153   FORMAT(21HSMALLEST MEAN ONE DAY/)
      GO TO 198
174   AR(K)=SUM7S(L,K)
      IF(1-K)198,184,184
184   CONTINUE
      WRITE(6,154)
154   FORMAT(24HSMALLEST MEAN SEVEN DAYS/)
      GO TO 198
175   AR(K)=SU30S(L,K)
      IF(1-K)198,185,185
185   CONTINUE
      WRITE(6,155)
155   FORMAT(25HSMALLEST MEAN THIRTY DAYS/)
      GO TO 198
176   AR(K)=S120S(L,K)
      IF(1-K)198,186,186
186   CONTINUE
      WRITE(6,156)
156   FORMAT(22HSMALLEST MEAN 120 DAYS/)
      GO TO 198
177   AR(K)=SXK(L,K)
      IF(1-K)198,187,187
187   CONTINUE
      WRITE(6,157)
157   FORMAT(11HYEARLY MEAN/)
      GO TO 198
178   AR(K)=SXS(L,K)
```

```
      IF(1-K)198,188,188
 188  CONTINUE
      WRITE(6,158)
 158  FORMAT(14HYEARLY STD DEV/)
 198  CONTINUE
 181  CONTINUE
 1011 CONTINUE
      DO 1010 I=1,NY
      DO 1020 K=1,NY
      IF(AR(I)-AR(K))1003,1004,1004
 1004 CONTINUE
 1020 CONTINUE
      MX=MX+1
      IF(MX-NY)1008,1008,1006
 1008 CONTINUE
      WRITE (6,1005) I,AR(I)
 1005 FORMAT(I5,F10.1/)
      AR(I)=0
 1003 CONTINUE
 1010 CONTINUE
      GO TO 1011
 1006 IAC=IAC+1
      MX=0
      GO TO 169
 179  CONTINUE
      IAC=1
 150  CONTINUE
      ISOMB=0.
      AAU=0.
      CX=0.
      JO=0.
      IF(NP-NSIM)92,92,101
92    END FILE 6
      END
```

BIBLIOGRAPHIC: Kerri, K. D., Complementary Competitive Aspects of Water Storage, FWPCA Publication No. DAST-1, 1969.

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